



The Journal of  
Laryngology and Otology



# The Journal of Laryngology and Otology

EDITED BY  
WALTER HOWARTH

WITH THE ASSISTANCE OF  
W. M. MOLLISON

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January 1946

## PENICILLIN IN OTORHINOLARYNGOLOGY

By C. A. HUTCHINSON (Salisbury)

THERE is no getting away from the fact that we are now in the Penicillin age and otologists have got to accept this fact whether they like it or not. Many extravagant claims have been made for Penicillin ; but, rather than allow ourselves to be carried away by the over-enthusiastic, it behoves us to survey the uses and limitations of the drug calmly and to try to see things in their correct perspective and to assess its true value in Otorhinolaryngology.

Our American colleagues have had the advantage of larger available supplies of Penicillin and far greater opportunities to try it out than has fallen to the lot of most of us in this country. Fortunately they have published their results in considerable detail and so made their valuable experience available to us.

In the following pages the writer has abstracted the main points in their publications and endeavoured to present them in co-ordinated sequence.

### A: PROPERTIES.

Penicillin is extremely hygroscopic and is highly water-soluble. It is relatively unstable and is easily destroyed by dilute acids. It rapidly loses its activity if exposed to the air, but retains it for 24 hours if kept absolutely dry. It penetrates the tissues freely and is not irritating to the mucous membranes. Its action is not impaired by the presence of serum, pus, blood or the products of tissue autolysis, while the number of organisms present has little effect on its bacteriostatic action<sup>1</sup>.



# C. A. Hutchinson

## B. MODE OF ACTION

It appears on the whole to have a primary inhibitory effect on the reproduction of organisms sensitive to it by inhibiting fission<sup>2</sup>, while the body defences actually destroy the organisms.

## C. THE SALTS USED AND THEIR CHARACTERISTICS

The sodium salt of Penicillin is a yellow powder, put up in glass ampoules mostly containing 100,000 Oxford Units. (An Oxford Unit (Florey) is the amount of Penicillin compared with an arbitrary standard, which completely inhibits the growth of a test strain of *Staphylococcus aureus*).

Both the sodium and calcium salts of Penicillin are used. The calcium salt is the more satisfactory as it appears to be more stable and less toxic than the sodium salt and may be handled more easily, while it may be kept for long periods without evident loss of activity<sup>3</sup>. It is suitable for local, intravenous, intramuscular and intrathecal administration<sup>4</sup>.

## D. APPLICABILITY

One of the essentials is to restrict the use of Penicillin to infections due to susceptible pathogens<sup>5</sup>; Another is to keep up adequate nutrition and a positive nitrogen balance in patients receiving Penicillin therapy<sup>6</sup>.

Most Gram-positives and Vincent's organisms are Penicillin-sensitive<sup>7</sup>; Its use should not be attempted for Gram-negatives. Certain organisms, notably the Colon bacillus group, contain substances which neutralize the inhibitory action of Penicillin: While *B. proteus* and some other Gram-negative bacteria grow freely in its presence.

- i. In *Staphylococcus aureus* infections results are satisfactory if the lesions are superficial, the infection localized, if adequate drainage is initiated and the disease is relatively acute. In cases, however, in which the condition is chronic, drainage is incomplete and sequestra or foreign bodies exist, the results have been unsatisfactory. In the case of infected, comminuted fractures the results have been equivocal.
- ii. In *Streptococcal* infections Aerobic and Anaerobic streptococci and the Lancefield streptococci (sulphonamide resistant) have given uniformly satisfactory responses. *Streptococcus viridans* infections have also reacted satisfactorily.
- iii. In *Pneumococcal* infections the response to Penicillin therapy has been satisfactory in Type 8 and Type 2 infections<sup>8</sup>.

It should be borne in mind, however, that even among usually susceptible pathogens certain strains are resistant. Therefore, except in an emergency, both Bacteriological and Sensitivity tests must be employed

# Penicillin in Otorhinc

before embarking on its use, which should be effective.

As regards virus infections there is as yet no evidence that the virus may be Penicillin-sensitive and yet be secured, which is possibly to be explained by the virus being fixed in the tissue cells before therapy was

## E THE METHOD OF PERFORMING SENSITI

3 Blood-agar plates are impregnated with Penicillin.

2 Blood-agar plates are impregnated with 10 per cent of Sulphathiazole.

All these five plates are then inoculated

## F. TOXIC REACTIONS AND CONTRA-INDICA

Very few toxic effects follow its clinical administration, and irrespective of which headache and dizziness may occur. Urticaria should it develop or other evidence of allergy manifest, such as maculopapular dermatitis, should lead to discontinuation of the drug. If the patient is exercised in continuing to administer the drug in the face of a generalized cutaneous allergic dermatitis. Probably such cutaneous reactions are attributable to Penicillin itself as to impurities. In such cases cutaneous reactions disappear on discontinuing the drug.

Local irritation may occur at the site of either intravenous or intramuscular injection.

Pyrexial reactions of varying intensity may occasionally occur. So long as Pyrogen-free Penicillin is employed such febrile reactions are unlikely—this entails ensuring that old rubber tubing and other apparatus prepared without due care are not employed.

There is no evidence of any disturbance being produced in either the peripheral blood or in the hæmopoietic system. On the contrary Penicillin can be used successfully in the presence of severe anaemia and even of actual agranulocytosis: While suppressed leucocyte counts have often been seen to rise in the course of Penicillin therapy in the face of overwhelming infection associated with suppression of bone marrow activity.

Patients receiving intrathecal Penicillin may sometimes show more severe and more persistent headache, pyrexia may be prolonged and the signs of meningitis subside more slowly<sup>11</sup>. Various writers have recorded the irritating effect of the drug on the meninges when given intrathecally—such irritating effect varying in degree with the use of Penicillin from

# C. A. Hutchinson

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# Penicillin in Otorhinolaryngology

after injection<sup>17</sup> Indeed some writers claim that even this level, which is definitely below that required to inhibit certain strains of *Staphylococcus aureus*, is not reached. Moreover the blood content drops rapidly during the second hour and the drug is not recoverable in the third hour. It may be mentioned that the average sensitive strain of this organism is inhibited by a concentration of 0.02 units per c.c., whereas even a concentration of 2 units per c.c. is of no avail against the most resistant strain.

Fleming's "slide cell test" has been found to be the most reliable means of determining the actual Penicillin content of the blood serum, it has the additional advantages of not requiring a sterile technique and of making the result soonest available.

## H. CONDITIONS OF STORAGE AND USE

Penicillin should be kept under sterile conditions in a refrigerator at a temperature of 4°C.<sup>18</sup> Fresh solutions should be made up daily in pyrogen free Physiological Saline for use. The syringe employed for making up the solutions should be sterilized by dry heat. A rigid aseptic technique is essential in the administration of the drug and it has been found of advantage to set aside a special Penicillin ward.

## I. METHODS OF ADMINISTRATION

1. *Intravenous* Penicillin disappears rapidly from the blood and is rapidly excreted—facts which have a distinct bearing on its use by this route.

(a) *Intermittent injection* If treatment is to be efficacious at least 8 intravenous injections are required in the 24 hours. In spite of its obvious disadvantages this method has, however, been used in some instances with satisfactory results.

(b) *Continuous intravenous drip* This is the method of choice for bacteriæmic cases. There are, however, certain difficulties.

1. The tendency to local venous irritation and thrombosis which, however, rarely produces permanent thrombophlebitis.

2. The possible occurrence of œdema, due to the use of excessive saline.

As regards the first condition, which only develops in some 5 to 10 per cent of cases careful inspection of the intravenous apparatus and changing both the apparatus and the site of injection at the first sign of irritation will be found to be adequate measures. The occurrence of œdema on the other hand may be avoided by using alternative Physiological Saline and 5 per cent Dextrose in distilled water as solvents.<sup>19</sup>

The continuous intravenous drip method is applicable whenever suitable veins are available, when, however, this is not the case one must

## C. A. Hutchinson

different sources of supply—the dark brown product having the greatest irritant effect. It would therefore appear that only the pale yellow product should be employed in intrathecal administration<sup>12</sup>.

Localized thrombophlebitis occasionally develops in a few patients but is of minor significance, it is apparently associated with certain—probably impure—brands of the drug. - Changing the site of injection is indicated.

### G. DIFFUSION OF PENICILLIN INTO VARIOUS TISSUES

The amount of active Penicillin in the blood can be measured by the power of the blood-serum to effect bacteriostasis<sup>13</sup>. This test lies behind the terms "Penicillin content", "Penicillin activity", "Bacteriostatic activity", "Concentration in the blood and tissue fluids", "Blood level of Penicillin", etc.

Florey, working on experimental animals, showed that Penicillin rapidly disappears from the blood after a single intravenous injection, and that a large percentage of the amount administered appears in the urine; that the actual blood concentration is less when the drug is given sub-cutaneously, but that a detectable amount is present for a longer period than when a single intravenous injection is given; that whatever the route of administration the drug is found in a more concentrated form in the Bile than in the Blood-stream, but that the total amount excreted by the Liver is small compared with that excreted by the Kidneys; that Penicillin is destroyed by the gastric juices, but can be absorbed from the intestines when care is taken to give it orally along with adequate amounts of sodium bicarbonate, so protecting it from being acted on by the gastric acids; and that the tears, pancreatic juice and the cerebrospinal fluid have no antibacterial activity when Penicillin is given intravenously, whereas it diffuses fairly freely into most other tissues.

These animal experiments have been confirmed for human patients<sup>14</sup>.

When Penicillin is introduced into the cerebrospinal fluid it remains there for at least 24 hours but disappears within 48 hours. When given intrathecally it can be detected in the blood, and there is some evidence to show that it passes more rapidly from the cerebrospinal fluid into the blood when the meninges are inflamed than when they are not<sup>15</sup>. Penicillin not only fails to reach the cerebrospinal fluid in detectable amounts when given intravenously<sup>16</sup> but also fails to do so when administered intramuscularly. Therefore in the treatment of infections involving the cerebrospinal structures it should be given intrathecally at least once daily.

With appropriate dosage by continuous intravenous drip the amount of Penicillin in the blood stream is 0.12 Oxford units per c.c.

With intramuscular administration of 25,000 units 3 hourly round the clock the blood Penicillin content is not more than 1 unit per c.c. 1 hour

# Penicillin in Otorhinolaryngology

in most types of case, though patients receiving intramuscular Penicillin 8 times a day for such a lengthy period are apt to become "needle shy". Local irritation may occasionally occur at the site of the injections, which are made with a standard 20 gauge intramuscular needle  $2\frac{1}{2}$  inches long

## 3 Local Application

- i Solution 100 to 250 units of Penicillin per c c of Physiological Saline are employed, preferably the latter concentration. Where practicable wet dressings are applied to the wound overlaid by an impervious material. The dressings are kept moist but changed only at 24-hour intervals. Occasionally deep seated areas of infection are treated by irrigating with the solution *via* rubber tubes<sup>21</sup>
- ii Powder (British) Weighed amounts of Penicillin are ground up with Sulphanilamide till a homogeneous powder results. The final mixture may contain up to 5,000 units per gramme. It is thought that Penicillin and Sulphanilamide may be synergic. The powder is available for use either by dusting on or by insufflation
- iii Cream (British) This is made up with 100 to 250 milligrammes of Penicillin per gramme in Lanette wax

In the treatment of severe and extensive inflammatory lesions uniformly satisfactory results are more likely to be obtained by the use of systemic Penicillin alone or combined with local therapy

4 *Intrathecal* In meningitis and infections involving the cerebrospinal structures, since Penicillin does not enter the cerebrospinal fluid when given intravenously or intramuscularly, intrathecal administration is indicated. Its use should, however, be supplemented by intravenous or intramuscular therapy<sup>24 25</sup>. A solution containing 1000 units of either the sodium or the calcium salt of Penicillin per c c in Physiological Saline is prepared. After removal of 10 c c of cerebrospinal fluid from 5000 to 10,000 units are, as a rule, introduced (though some clinicians give up to 20,000 units). Injection should be repeated every 12 to 24 hours till 3 negative cultures from the cerebrospinal fluid have been obtained<sup>26</sup>

5 *Subcutaneous* Penicillin may be administered intermittently or continuously by this route. Its absorption, however, is erratic and variable as is the case with all subcutaneous fluid injections, and concentrated solutions may prove irritating<sup>27</sup>

## J SUMMARY OF RESULTS OBTAINED AND DETAILS OF CERTAIN PROCEDURES

1 *Vincent's Infection* (Lesions of fauces, pharynx and tonsils)  
Swabbing 4 times a day with 250 units per c c in Physiological Saline,

plus intramuscular injections in severe cases of an initial 250,000 units and 15,000 units 3 hourly thereafter is the most effective treatment to date<sup>28</sup>.

2. *Bacteriæmia*. 89 per cent. recovered satisfactorily<sup>29</sup>. The question of dosage is controversial. Some authorities hold 80,000 to 100,000 units intravenously in 24 hours to be the most satisfactory average dose.

In the treatment of (a) and (b) hæmolytic streptococcal and pneumococcal infections other clinicians recommend 100,000 to 150,000 units per 24 hours intramuscularly in divided doses at 3 hour intervals. In the case of severe staphylococcal infections they advocate 100,000 units intravenously during each 8 hour period at the outset; subsequently as improvement takes place intramuscular administration may be adopted<sup>30</sup>.

The War Department Technical Bulletin of Medicine, however, stresses the need for the 24-hour dosage of 400,000 units for seriously ill patients with *Bacteriæmia*, especially in severe staphylococcal infections<sup>31</sup>.

3. *Severe Cellulitis without Bacteriæmia*. 88 per cent. responded satisfactorily, while 12 per cent. failed to respond or gave doubtful results. The organisms present were *Streptococcus pyogenes*, *Staphylococcus aureus*, or mixed organisms<sup>32</sup>.

4. *Post-operative Wound Infection*. 87 per cent. were treated entirely satisfactorily, the organisms present were *Streptococcus pyogenes* and *Staphylococcus aureus*<sup>33</sup>.

5. *Meningitis*. As a general rule unless susceptible bacteria are actually found in the cerebrospinal fluid intrathecal Penicillin should be withheld: The presence of meningeal irritation and the cerebrospinal fluid findings of increased pressure and increased leucocytes do not in themselves constitute adequate reasons for intrathecal administration. In some cases however, it is unsafe to withhold intrathecal Penicillin therapy pending the results of cerebrospinal fluid culture<sup>34</sup>.

*Technique*. After doing a diagnostic lumbar puncture a certain amount of cerebrospinal fluid is withdrawn—precisely how much, however, is a controversial point. Some authorities advocate removing 10 c.c., others advise removing as much as possible and even go so far as to advocate aspiration, while the writer's practice is to reduce pressure to between 100 and 110 millimetres of mercury under manometric control, and if plastic meningitic changes render withdrawal of cerebrospinal fluid and reduction of the pressure by lumbar puncture inadequate he elects to do a cysterna puncture and withdraw it by that route.

10,000 units of sodium or calcium Penicillin in 10 c.c. Physiological Saline are then slowly introduced<sup>35</sup>. Further 10,000 unit doses are administered intrathecally at 24 hour intervals (with preliminary removal of cerebrospinal fluid as above) until clinical improvement, sustained fall in temperature, and/or a decrease in the meningeal signs are manifest,

## Penicillin in Otorhinolaryngology

and until smears and cultures have yielded a negative result<sup>36</sup>. Persistence of coma, however, needless to say, indicates further intrathecal therapy, while in severe infections and in those in which coma has lasted for 48 hours or more intrathecal Penicillin should be continued until the cerebrospinal fluid is bacteria free on three successive days<sup>37</sup>.

Combined with the intrathecal therapy, Penicillin should also be given either intravenously by the continuous drip method at the rate of 5,000 units per hour, or intramuscularly in doses of 15,000 units 3 hourly, reducing this to 10,000 units 3 hourly if improvement is satisfactory. As a rule intravenous Penicillin is given (as 40 units per c.c. in 5 per cent. Dextrose solution) for the first 8 hours and continued intramuscularly thereafter. In a fulminating case, however, give intravenous Penicillin at the rate of 10,000 units per hour to start with for 4 hours. Patients should also receive 3,000 c.c. of fluid daily<sup>38</sup>.

To combat shock in the fulminating type of case, supportive therapy should be employed in the form of whole blood, plasma, Epinephrin and Desoxycorticosterone acetate; Oxygen should also be given as indicated.

- i. *Hæmolytic streptococcal meningitis*. (3 cases—all recovered.) On an average 2 intrathecal injections supplemented by 170,000 to 650,000 units of Penicillin intravenously and intramuscularly over periods ranging from 39 hours to 8½ days sufficed. The temperature returned to normal in 4 to 6 days<sup>39</sup>.
- ii. *Streptococcus viridans meningitis*. (2 cases—both recovered.) 3 to 4 intrathecal injections supplemented by 40,000 to 130,000 units intravenously and intramuscularly over periods of 3 and 4 days respectively sufficed. The temperature returned to normal in 3 to 5 days. There were no sequelae, though both patients were comatose for 24 hours after therapy was begun<sup>40</sup>.
- iii. *Pneumococcal meningitis secondary to acute otitis media*. (1 case—recovered.) 3 intrathecal injections supplemented by 800,000 units intravenously and intramuscularly over a period of 10½ days proved satisfactory. The temperature returned to normal on the fifth day but intramuscular therapy was kept up for fear of bony suppuration in areas adjacent to the middle ear till the temperature had remained normal for 5 days. No surgical intervention was, however, necessary. Another writer obtained excellent results in 22 cases of otitic meningitis by giving 15,000 units intrathecally repeated 24 hourly and supplemented by 15,000 units intramuscularly 3 hourly round the clock; in several cases mastoid surgery was avoided.

It is evident, therefore, that prolonged periods of intrathecal therapy are unnecessary; but when meningitis is secondary to otitis media intravenous or intramuscular Penicillin must be continued until all other possible sources of infection have been



## C. A. Hutchinson

adequately controlled. Finally, Penicillin may prove life-saving for patients with meningitis due to sulphonamide resistant organisms<sup>41</sup>.

6. *Pulmonary suppurative disease.* (Pneumonia, pulmonary abscess, empyema.) 85 per cent. gave satisfactory results, but on the whole the Type 3 *Pneumococcus* appears to be less likely to respond to the treatment<sup>42</sup>.

7. *Bronchiectasis.* No clinical experience is available as yet for a report on its response to Penicillin therapy.

8. *Acute otitis media.* Most acute ear infections are due to Penicillin sensitive organisms. Intramuscular Penicillin may be effective in rendering operation unnecessary. The point is that the infection must be caught in the early acute stage and treatment should be maintained after apparent recovery to avoid possible relapse<sup>43</sup>. One writer in particular found that in several hundred such cases the results have been uniformly good. The treatment consists of giving 15,000 units intramuscularly 3 hourly round the clock for about 7 days, or until the tympanic membrane has resolved and the landmarks return: Then reduce dosage to 10,000 units at the same intervals and keep that up for 3 to 4 days, while finally 5,000 units at the same intervals should be given for a further 3 to 4 days.

The Penicillin Committee now sanctions the use of Penicillin initially in acute otitis media in place of the sulphonamides, this should give even better results.

9. *Acute labyrinthitis.* Continuous intravenous drip administration may prove successful. On the average 455,000 units are required<sup>44</sup>.

10. *Acute mastoiditis*

i. *Pre-operative Administration.* The consensus of opinion appears to be that infections of the mastoid and contiguous structures can be readily controlled by Penicillin, provided the organisms are sensitive to the drug and that sterilization of the blood-stream and control of spreading infection can be accomplished by the systemic administration of Penicillin. The response to this therapy being dramatic in its rapidity—within the first 48 hours of administration there was a decided decrease in pain with a general feeling of well-being—but since Penicillin will not eliminate pus if drainage be inadequate surgical intervention is usually necessary to effect cure<sup>45</sup>; and it should be remarked that this satisfactory result is obtainable even when the combination of sulphonamides and surgery have failed. None of the causative bacteria (the majority have been streptococci and staphylococci) have become resistant, and it is thought that the failure of organisms to respond is due to infection by a resistant bacterial strain<sup>46</sup>: a fact which emphasizes the importance of testing for sensitivity as soon as possible.

# Penicillin in Otorhinolaryngology

Originally the Penicillin was given by one of the two intravenous methods, but this has now been replaced by intramuscular administration, though the continuous intravenous drip may still be preferred for extremely ill patients with grave infections, when a high, prolonged blood concentration is desirable. The dosage employed is 25,000 units 3 hourly, reduced to 15,000 units 3 hourly as the patient improves<sup>47</sup>.

- i. *Administration at Operation.* Mastoidectomy may be supplemented by the administration of Penicillin either intramuscularly or by local instillation into the mastoid cavity (Florey).

The latter is accomplished by inserting a rubber tube, preferably into the upper end of the mastoidectomy wound—when gravity to some extent aids retention—and closing the remainder of the wound. Penicillin is then instilled *viâ* the tube and the latter is sealed off. Every 6 hours the exudate should be aspirated (according to some writers this is unnecessary) and fresh Penicillin instilled, sealing off the tube after each such instillation. Frequent drainage should never be allowed. This routine is employed for 5 days and an average of 17,300 units per case is required. The ear usually becomes dry within 5 days<sup>48</sup>.

While Penicillin appears to hasten recovery from any pre-operative facial paralysis, which may be present, there is still some difference of opinion as to whether we really are able to shorten the convalescence of the average uncomplicated case of acute surgical mastoiditis appreciably. On the other hand in acute mastoiditis with complications (e.g. meningitis, septicaemia or Bezold's abscess), convalescence would appear to be definitely shortened.

- iii. *Post-operative Administration.* Penicillin may be used locally with advantage, either by packing the open wound with Penicillin at the daily dressing or by substituting closed instillation after Florey's method when secondary closure has been performed. Lastly, the healing of indolent wounds, which continue to discharge after mastoidectomy may be hastened by the local application of Penicillin<sup>49</sup>.

ii. *Chronic suppurative otitis media.* Some authorities have secured satisfactory results by instilling Penicillin by the "Replacement Method", sealing it off by means of cotton wool impregnated with a bland ointment. This procedure is repeated 6 hourly and kept up for 8 days. A total of 10,000 units will probably be required<sup>50</sup>.

The most suitable conditions for success are :—A sensitive organism, a large perforation, no granulations and no evidence of cholesteatoma. If, however, cholesteatoma or aural polyposis be first eradicated by

## C. A. Hutchinson

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## Penicillin in Otorhinolaryngology

spread of the disease, but that is it of limited use only in this respect as shown by the fact that thrombosis has been known to occur after the patient had been placed on Penicillin therapy

It is an open question as to whether it is necessary to ligate the jugular vein, certainly many cases have recovered rapidly when this had not been done. Intramuscular Penicillin should be given for 24 hours before operation and in many cases cultures from the thrombosed sinus will be found to be sterile at operation. As a general rule suitable dosage has been found to be 25,000 units intramuscularly every 3 hours, reduced to 15,000 units as improvement results. The response to the therapy is rapid and is shown by a prompt drop in temperature, disappearance of headache, general feeling of improvement and sterilization of the blood stream

- Some writers claim that organisms may occasionally become Penicillin fast, but it seems more reasonable to suppose that infection was due to an initially resistant strain. Penicillin sensitivity should therefore be tested for in every case as soon as possible

Generally speaking the most gratifying results have been secured in the acute cases. In the more chronic types of case the results have been hard to evaluate, since the infection can be brought under control so long as the patient is actually receiving Penicillin but there is a definite tendency for the infection to again become active when administration of the drug is discontinued

There is some evidence to show that the response is more satisfactory when intravenous Heparin is given in addition to Penicillin—the former apparently rendering the Penicillin more freely available locally\*

15 *Cavernous sinus thrombosis* Intravenous Heparin combined with intravenous Penicillin may lead to the blood cultures rapidly becoming negative with eventual complete recovery. The rationale would appear to be the same as for the above

16 *Peritonsillar and lateral pharyngeal abscesses and acute ulcerative pharyngitis* (Usually pneumococcal) These conditions respond satisfactorily to intramuscular Penicillin but in the case of the abscesses recovery will be expedited if incision and drainage be performed as well

17 *Osteomyelitis of the facial bones* Whereas in severe cases the mortality rate of this dread condition is 80 per cent there is some justification for the hope that this present high mortality rate, whether the condition be acute, sub acute or chronic, will be drastically reduced with the wider adoption of carefully planned Penicillin therapy

Gratifying prophylactic results have been secured in bone surgery, when the drug has been administered both locally and intramuscularly

It should be particularly stressed that in the active treatment of osteomyelitis Penicillin has not supplanted surgical procedures but hel

materially in combating the disease<sup>53</sup>. Surgical measures such as sequestrectomies, removal of foreign bodies and the initiation of proper drainage are procedures without which Penicillin will not avail in the majority of cases. In contrast to the sulphonamides Penicillin prevents further spread of infection so that either before or after sequestration has occurred devitalized bone can be removed surgically. Moreover, infective granulations become healthy and purulent discharging Sinuses dry up under the influence of the drug. The organisms primarily responsible are probably in many instances anaerobic non-hæmolytic streptococci in addition to the more usual *Staphylococcus aureus*, etc. Penicillin has proved equally effective against sulphonamide-resistant organisms as for those which have not undergone sulphonamide therapy<sup>54</sup>.

- i. *Acute and Sub-acute cases.* It would appear that the optimum time for operative measures in acute spreading osteomyelitis is during the period in which the infection has been checked by Penicillin; However it may well be that in certain acute cases if treated early and adequately the disease process may be stopped and healing take place without radical surgical procedures. In cases which continue to show progressive bone destruction in spite of adequate Penicillin therapy surgical intervention may be accomplished with little risk after the wound has become dry and the cultures have become negative with subsidence of the surrounding cellulitis: It may require anything from 1 to 2 weeks of the therapy to attain this state<sup>55</sup>.
- ii. *Chronic cases.* In chronic Osteomyelitis of the Frontal Bone it is sometimes possible to obtain healing under Penicillin therapy without resorting to extensive surgery, and a thorough trial of the drug in adequate dosage lasting over a long period—possibly many months—may be necessary. When, however, there is no regression under this form of treatment the involved Sinus should be operated on, and there is evidence to show that this procedure in combination with the therapy may prevent further extensive operations<sup>56</sup>.

Due caution should, however, be taken in accepting Radiographical findings as evidence of improvement and healing, for at operation extensive necrosis may be found. Occasionally Brain Abscess, Extradural Abscess and Orbital Cellulitis develop in spite of Penicillin therapy. Needless to say in the case of the last named condition the underlying Sinus disease calls for energetic surgical measures.

The question of dosage is still controversial. Patients given small amounts for only a few days tend to show frequent relapses: Prolonged treatment with larger doses on the other hand prevents relapses and possibly shortens the course of the disease. The

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present policy is to give 200,000 units daily by continuous intravenous drip for 10 to 14 days; followed by 15,000 units intramuscularly every 3 hours (120,000 units daily) for another 2 to 3 weeks; and if surgical intervention is delayed until sequestration has occurred Penicillin should be continued for at least a week post-operatively.

Lastly the adoption of periodic Penicillin irrigation as well as intramuscular Penicillin in combination with adequate surgical procedure has given most encouraging results, far better than had been secured by intramuscular Penicillin plus surgery alone.

18. *Suppurative sinusitis.* Cases were treated with Penicillin both locally and systemically.

*Acute antral infections.* These have been reported as cured after several irrigations with Penicillin, even when the organism was a staphylococcus resistant to other therapy. The strength of the solution used being 250 units per c.c. In other cases a few days of systemic Penicillin therapy has secured rapid subsidence with disappearance of the causative organisms<sup>57</sup>.

i. *Chronic antral infections.* Cultures became sterile but the discharge continued in spite of the above treatment and at operation the mucosa was found to be thickened with chronic inflammatory changes. A new technique was accordingly adopted along the following lines.

The antra were irrigated and swabs taken for culture from the nasal passages as well as the antral washings. These were then tested for sensitivity to Penicillin and the sulphonamides. The antra were then filled with a radio-opaque substance and radiographed. Spinal needles were introduced into the antra (the author prefers to use Lichwitz cannulas fitted with spigots) and allowed to remain in place for 24 hours, during which the patient kept his head upright. 3 hourly injections of 5 c.c. per antrum of a solution contain 1,000 units of Penicillin per c.c. (100,000 units dissolved in 100 c.c. N/1 saline) for 8 doses were given—the spigot being replaced after each injection. There were no unpleasant reactions and immediate signs of general improvement. On the third or fourth day fragments of polypoidal mucosa were blown out. On the sixth day the nose was almost free of purulent discharge, when a submucous resection and the removal of any remaining obvious polyp was then done if necessary. 6 days later cultures of the nose were found to be sterile though the Antral washings still grew staphylococci. The antra were, therefore, re-radiographed for comparison. The Penicillin was then repeated with the same procedure. 7 days after both the antral washings were found

to be clear and the bacteriological examination negative. Further observation for 15 days showed no evidence of return<sup>58</sup>.

The combination of minor surgical procedure and the local use of Penicillin may therefore obviate radical procedure and shorten hospitalization, besides offering efficacious therapy in the case of patients, who for any reason are unfit for or unwilling to undergo operative treatment. It would seem therefore that the use of Penicillin for sinusitis is worthy of further trial.

19. *Chronic suppurative dacryocystitis.* The lachrymal passages were irrigated daily with 2 c.c. of 500 unit solution. The results were satisfactory. Similar daily irrigations were employed with excellent results withing 24 hours after dacryocystorhinostomy<sup>59</sup>.

20. *Orbital cellulitis.* Intramuscular Penicillin combined with irrigation of the abscess caused the cellulitis to respond rapidly and the associated purulent sinus discharge to clear off in 48 to 72 hours<sup>60</sup>. In the author's opinion, however, if permanent cure and freedom from relapse is to be secured, adequate sinus surgery in addition to the above is essential.

A fair summary would therefore appear to be that the golden age has not yet come; Penicillin has by no means ousted, and is not likely to oust, surgery from the province of otorhinolaryngology. It tends on the other hand to increase considerably the scope of such surgery and when used along carefully planned lines to suit individual cases is a most useful ancillary to appropriate surgical measures. Indeed it renders the prognosis in certain hitherto hopeless conditions, for example cavernous sinus thrombosis, so much more hopeful that we can confidently look forward to a material reduction of their mortality rate. In the above pages the author has amassed the evidence of many American writers: He, however, has tried out certain of the techniques recommended and from personal experience can testify to the justification for their hopeful views; and, lastly, he is collecting a series of cases which in due course he hopes to publish.

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# Congenital Sinuses of the External Ear

cent.), but Stammers<sup>3</sup> in this country looked for examples among 500 consecutive in-patients in hospital without finding it once. In some races the incidence is high and the condition has been known for a long time to be very prevalent among the Chinese. Selkirk<sup>7</sup> (in a paper in which he records in all 518 cases) found in a mixed population of negroes and whites, an incidence of 5.2 per cent. in the former (18 cases in 346 examinations) as compared with 0.9 per cent. (34 in 3,660 examinations). Stannus (quoted by Wood Jones<sup>5</sup>) gives a figure of over 4 per cent. among the African negroes of Nyasaland, but Khanna<sup>8</sup> in India found only 7 cases in 6,800. It is of interest to note that in this area its presence was thought to be a good omen. The possessor of such a deformity, more especially if bilateral, being considered to be a born "Yogi".

## Laterality

The condition was bilateral in 7 cases (23 per cent.) and unilateral in 24 (77 per cent.). Of the unilateral cases right and left occurred with almost equal frequency. In each case there was only one fistula on the affected side or sides, except in one unilateral case where there was a double fistula. This case will be mentioned again later in the paper. Other figures for comparison are:—

	Bilateral	Unilateral
Stannus	17%	83%
Urbantschitsch	25%	75%
Selkirk	23%	77%

## Position

The sinus was in most cases situated close to the anterior margin of the cartilage of the ascending limb of the helix (as pointed out by Selkirk<sup>7</sup> the line of direction of the antihelix passes in most cases exactly through the opening of the fistula). Congdon *et al.*<sup>4</sup> in their exhaustive paper gave a precise classification of all sinuses according to their anatomical position. Those situated close to the anterior border of the ascending limb of the helix they called marginal helicine, and to this group 90 per cent. of cases belong. We have made no attempt to separate this group from their next which was called preauricular. In this variety the opening of the sinus is said to be found anywhere on an area immediately in front of the tragus, and in the majority of cases is associated with what are thought to be congenital scars in the skin in front of the pinna. This feature was neither sought nor observed in any of our cases. One example of their next group, crural, was found. It took the form of a well-marked sinus a few mms. deep, opening in the middle  $\frac{2}{3}$  of the crus on its lateral side. The opening could be readily probed, its blind end being posteriorly. On the same ear was a marginal helicine sinus.

Congdon<sup>4</sup> added 11 cases to the only one then recorded and Selkirk<sup>7</sup> described 8 more, in several of which there were associated marginal helicine sinuses on the same or opposite side.

No examples of the less common post-helicine or lobular varieties were seen.

### Depth

In 10 cases the sinus was only deep enough to engage the tip of a fine probe, the opening having on several occasions to be first gently dilated. In a few cases the opening was very wide so that the sinus was funnel-shaped rather than tubular. One was over 6 mm. long, but the average depth was no more than 3 mm. Shallow sinuses are much more common. Paget's original case measured  $\frac{1}{2}$  inch and one case of 22 mm. has been recorded.

In no case could any communication be demonstrated with the external auditory meatus or with the middle ear cleft. Schmitz in 1873 endeavoured in vain to inject water into the tympanum through such a fistulous opening. Although it is said (Nelson, Med. Ear 1939) that rare cases do occur, in which a communication exists between a true auricular sinus and the ear, we have not been able to trace an authenticated case in the literature.

### Association with Other Abnormalities

In no case was the condition found in association with any other abnormality. Paget in his original description told of a family where there occurred co-incidentally in several members branchial and aural fistulae. He reported Heusinger as having recorded a similar case in 1804, and Urbantschitsch<sup>6</sup> also mentions an example. Selkirk<sup>7</sup> in his records of 518 cases in children found in no case any branchial remains. There was also no increased incidence of the condition among a group of children (in a cripples' hospital) having other congenital abnormalities.

Paget<sup>1</sup> also noted that many of the subjects affected by fistulae had become deaf. He found it "hard to believe so great frequency of defective hearing in the subjects of aural and branchial fistulae should be casual". In all of our cases hearing was up to standard I.

In no case were any aberrant auricles found, although as Wood Jones<sup>5</sup> has pointed out that the site of maximum incidence of the two conditions in large measure corresponds.

### Family History

That the condition is in many cases hereditary, has been recognized since Paget's original description of a family in which the father and 5 of his 8 children presented this deformity. A definite family history was elicited in only one of our cases. The patient's brother and father also



Photograph shows marginal helix (indicated by probe) and crural  
sinuses together



# Congenital Sinuses of the External Ear

being affected, but whether or not on the same side, it was not possible to determine. To students of heredity the condition is of much interest. The anomaly is transmitted as an incomplete dominant, being quite variable in its occurrence (McDonough<sup>9</sup>: Cannon<sup>10</sup>). Persons in whom the pit is absent, may have pitted offspring. Quelprud<sup>11</sup> found the condition 17 times in the study of a large family group of 150. It was claimed by one family as its coat of arms. It has even been suggested that in some cases, its presence may be useful in determining cases of doubtful paternity.

## Symptoms

In approximately  $\frac{1}{3}$  of the cases the patient was aware of the existence of a sinus; to the remainder, the knowledge of its presence came as a complete surprise. In only one case was there a history of an intermittent discharge of "white stuff". Urbantschitsch<sup>6</sup> described a case where a swelling the size of a pea appeared from time to time in front of the ear which was emptied of its secretion by pressure. The material so obtained resembled in all respects that coming from other congenital fistulous openings in the neck. One case was mildly infected. The patient had noticed a pimple on each ear for many years. It resembled a small acne spot and had at no time caused any great discomfort or required incision. Infection occurring in an auricular sinus must be borne in mind as a not uncommon cause of a recurring abscess in front of the ear. Many such cases are recorded (including 2 by Stammers<sup>3</sup>), the abscess being not uncommonly incised several times, before its true nature is recognized and the condition finally eradicated by excision of the sinus *in toto*. Klaber<sup>12</sup> described a patient with a granuloma in front of the ear which came under the care of the dermatologist as a suspected lupus and which was subsequently discovered to be due to an infected sinus. There was a positive family history.

## Pathology

We have not had an opportunity of exploring an auricular sinus surgically or of examining one on section. Congdon<sup>4</sup> had sectioned 3 of the marginal helicine type and found its walls to be entirely cutaneous with no peculiarity as to hair or glands. They were as a rule cylindrical on section, one having a diverticulum. On the other hand Becker and Brunschwig<sup>13</sup> excised one and found it to be lined with columnar epithelium.

## Embryology

It is when one comes to consider the probable causation of this anomaly that one comes across such a wide conflict of opinion. There are two main theories:

1. That the condition is derived from the first branchial cleft.

## M. R. Ewing

2. That it has its origin in the faulty union of the 6 tubercles (first clearly described by His) round the posterior end of the first cleft which fuse to form the external ear.

The majority of those who have studied the problem would seem to favour the second, but Wood Jones<sup>5</sup> in a convincing paper makes out a very strong case for the former as the more likely solution. He points out (1) that the hillocks which go to form the external ear are at all stages of development so small and inconspicuous—he had, indeed infinite difficulty in recognizing them all at and “low swellings never separated by any degree of distinctness” was how Streeter described them—that it was hard to imagine any sort of fistulous track being formed between them as they join. (2) The distribution of the sinuses does not appear to follow the line of fusion of the tubercles as they have been described by His and Streeter. As the result of a painstaking study of the external ear in the developing foetus, he concludes that the major part of the ear, with the exception of the tragus, is derived from the hyoid contribution. [As additional supporting evidence he points out (a) that in cases of congenital absence of the mandibular arch (agnathia) the pinna is completely formed but for the tragus, and (b) from careful study in cases of anæsthesia he maintains that the area of sensory innervation of the Vth cranial nerve is limited to the tragus.] The line of the first branchial cleft is thus made to correspond to the line of maximum incidence of the auricular sinus.

Congdon and his collaborators, on the other hand, marshal equally convincing evidence in support of the second theory, pointing out, in the first place, that no one has been known to have found a connection between one of these sinuses and derivatives of the first pouch or groove. While admitting that the inter-tubercular grooves are always shallow and indistinct, he puts forward the hypothesis, that the depth of the sinus is determined by shifting of the skin of the auricle at one stage in development, the skin being presumably more firmly anchored to the underlying tissues at the site of each intertubercular groove. There is a distinct correspondence between the axes of the various types of sinus and the anticipated lines of skin traction (associated, for example, with the rapid development of the lower jaw and the cranial vault). It was he too who drew attention to the frequent occurrence, in association with pre-auricular sinuses, of congenital scars of the skin. These resembled in some respects striae gravidarum and he suggests that each is due to overstretching of the skin, one during development, the other during pregnancy.

### Summary

In a series of recruits the ears were examined for the presence of auricular sinuses. The results of this examination are recorded along with some observations on the subject in the literature.

# Congenital Sinuses of the External Ear

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# FENESTRATION OF THE LABYRINTH

By O. POPPER (Johannesburg)

## PART I.

### The Transtympanic Route

READERS of this Journal will be fully acquainted with recent developments in fenestration, and, in spite of some undesirable lay publicity, none will be disposed to ignore its tremendous implications.

This paper will deal with

1. A new, safer and less traumatic approach to the labyrinth—the transtympanic route ;
2. Alternative sites for fenestration rendered accessible by this new approach ;
3. Other otological procedures *viâ* the transtympanic route opening a new vista in this branch of surgery.

The Lempert papers, and more particularly the address published in the *Archives of Otolaryngology*, January, 1945, have created a situation of some urgency to otologists. Claims that fenestration restores hearing in otosclerotic deafness have been established by various workers for the past seventy years from Kassel to Holmgren, Sourdille, Jenkins, Bárány, Simson Hall and Lempert, to mention only a few. This aspect will not be discussed and readers are referred to the more recent publications.

Lempert claims, and it would appear justifiably, to have triumphed over the main cause of failure—the osteogenetic closure of the fenestration after a few weeks or months by the insertion of a shaped cartilage into the newly created opening in the labyrinth.

He further claims that his "mobile cartilaginous stopple" has banished another cause of defeat—post-operative labyrinthitis. Both the lapse of time and the clinical material at my disposal are insufficient for me to make an evaluation or to comment on these claims.

The records of more than a thousand cases support Lempert in that a very large proportion of these had useful hearing restored—that is, such cases responded to airborne sound with an intensity of less than 30 decibels, and this improvement was maintained for a period of years.

Simson Hall, although reporting on a vastly smaller number of cases, and adopting a more cautious attitude, reports 55 per cent. successful results.

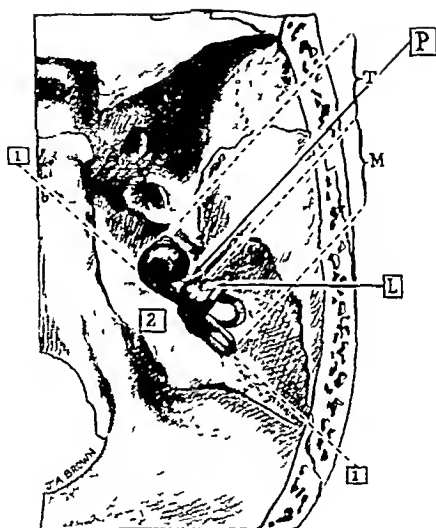


FIG 1

- 1 1 Axis of Labyrinth shows its inclination of 45 degrees to Sagittal plane
- M Part of Labyrinth covered by Mastoid
- T Part of Labyrinth covered by Tympanic Plate
- P Arrow shows direction of Transtympanic approach and Square On presentation of Vestibule
- L Arrow shows direction and oblique presentation by Mastoid approach
- 2 is opposite Vestibular region of Labyrinth

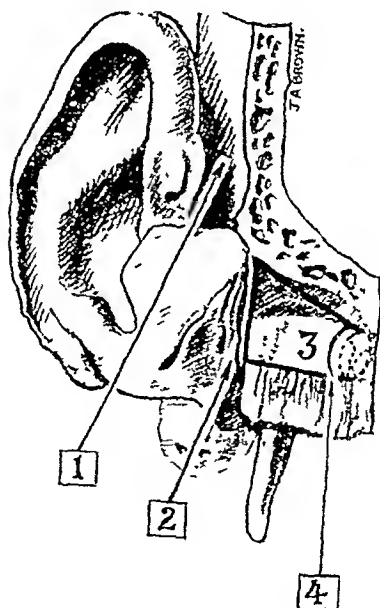
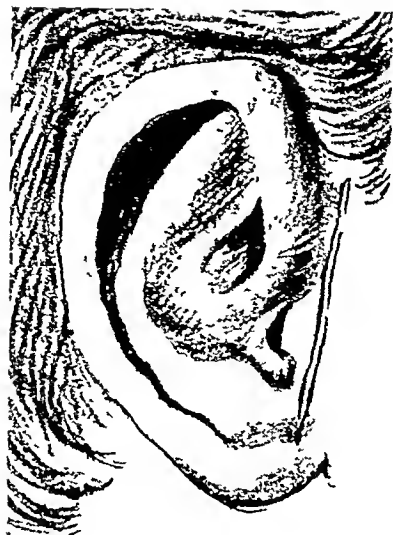


FIG 2.

THE FOUR STEPS OF THE TRANSTYMPANIC APPROACH

- 1: First incision through skin down to cartilage
- 2: Second incision through attachment of cartilage to Tympanic Plate
- 3: Removal of Tympanic Plate
- 4: Incision through skin of Meatus

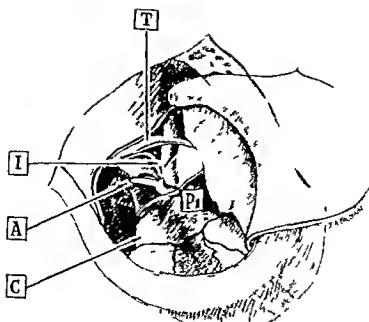


FIG. 3

REFLECTION FORWARD OF THE SKIN OF THE MEATUS PLUS THE TYMPANIC MEMBRANE—  
THE TYMPANONEATAL FLAP—REVEALS MIDDLE EAR

- T Chorda Tympani
- I Long process of Incus attached to head of Stapes
- A Tendon of Stapedius Muscle
- C Round Window
- P<sub>1</sub> Site of Fenestration in Cochlear Vestibule

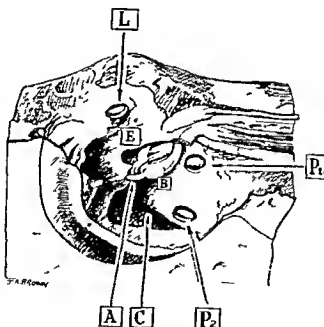


FIG. 4

#### SITES OF FENESTRATION

The Tympanic and Epitympanic space after removal of the Attic Wall and Incus  
(Chorda Tympani Drum and Malleus not shown)

- L Fenestration in Vestibular Dome (Lempert)
- E Facial Nerve
- A Tendon of Stapedius
- C Round Window
- P<sub>1</sub> Fenestration in Cochlear Vestibule
- P<sub>2</sub> Fenestration in Scala Tympani



## Fenestration of the Labyrinth

This technical advancement—the prevention of closure by osteogenesis—rounds off a period of experimental research. Theoretically, every otologist should now be in a position to attempt this operation.

Lempert issues a warning that "no surgeon, however skilful, should attempt this operation without special training in this type of surgery under supervision and guidance." Why should this be? The explanation is that by the mastoid approach—whether post aural or endaural is quite immaterial—the preliminary operation is a radical mastoid. Then the long meatal flap, of doubtful viability, continuous with the tympanic membrane must be carefully fashioned—another arduous, time consuming step.

And after all this, when the incus and head of the malleus have been removed, one is presented with an obliquely receding field consisting of the lateral semicircular canal and its ampulla and the roof of the vestibule. The axis of the labyrinth slopes at an angle of  $45^{\circ}$  to the sagittal axis of the skull (Fig 1).

The hazards of operating on the vestibule are immensely increased by this oblique presentation. It is quite impossible with the mastoid approach to get a "square on" view and "square on" working field of this site for fenestration.

This obliquity contributes in large measure to the difficulty and danger of the operation. Actual fenestration is performed, be it remembered, at the end of very exacting preliminary procedures.

We are all agreed that the ampulla is a better site for fenestration than the external semicircular canal and very many will support Lempert and Simson Hall in the claim that the roof of the vestibule is better than the ampulla.

In the last seventy years the site of fenestration has thus crept forward from the semicircular canal to the ampulla, and finally to the very roof of the vestibule itself. The mass of evidence favours the vestibule as the site of choice for fenestration. The approach, however, has remained essentially the same—through the mastoid. The mastoid route is clearly suitable to reach the semicircular canal—which is a structure covered by the mastoid portion of the temporal bone.

The ampulla, however, already encroaches on the tympanic portion of the temporal bone and as for the vestibule-roof, dome, or "cochlear vestibule"—these are emphatically tympanic and epitympanic structures. The dome of the vestibule—the site of hundreds of recorded successful fenestrations—is in immediate relationship to the epitympanic space and the lower portion of the vestibule is correspondingly a tympanic structure. The lateral wall of the vestibule is largely the internal wall of the tympanic cleft.

I contend that, before the operation for fenestration can hope to enjoy popularity and be performed with a degree of essential competence by a

## O. Popper

large number of otologists in every quarter of the globe, a complete reorientation of ideas on the surgical approach to the vestibule must take place.

To approach tympanic structures through the mastoid would seem a surgical absurdity, and, until otologists come to grips with this anachronism, so long will this operation remain in the hands of the very few. The transmastoid route for fenestration operations on any part of the vestibule, is not only unnecessary, but undesirable; this quite apart from operating under adverse conditions on an obliquely receding field.

Trauma incident on mastoid exenteration is massive, and severe post-operative œdema is unavoidable. This inflammatory reaction is, at best, purely post-traumatic and sterile or non infective, yet it may ruin the chances of hearing recovery after fenestration. With the best aseptic technique and most favourable conditions, many cases will become infected—bacterial invasion of devitalized bare bone is difficult to control. Months of suppuration after fenestration is not uncommon, and is not without its special danger where the labyrinth has been exposed. Bone tissue is notoriously liable to a form of low grade chronic sepsis. It is possible that the differing reports on fenestration, ranging from success (Lempert 80 per cent. and Simson Hall 55 per cent.) to failure can be partly explained by the better approach technique of these workers, rather than the actual fenestration procedure.

### THE TRANSTYMPANIC ROUTE :

I believe the transtympanic approach will tend to popularize the fenestration operation in that a larger number of competent surgeons will be tempted to undertake this admittedly delicate and exacting work. Operating with magnification requires practice and acquisition of such experience is the first and primary qualification.

Once the surgeon is assured of a "square-on" presentation of his field, easy access, perfect hæmostasis and, above all, superlative landmarks and perfect visual control—however delicate the manipulation demanded, the major terrors of fenestration are banished. Moreover, the fact that exposure of this field can be comfortably accomplished in thirty minutes without touching the mastoid is an incaluable advantage. The tympano-meatal flap can be prepared in fifteen minutes, instead of an hour or more required, when skeletonizing the long bony meatus, with the danger of tearing ever present, necessitating abandonment, or a two-stage operation.

In contra-distinction to the back door or mastoid approach, where the surgeon works from behind the ear, in the transtympanic technique the field is approached from the front—the patient's face is turned towards the surgeon.

# Fenestration of the Labyrinth

## ANÆSTHESIA

Immobility of the patient is essential when working with magnification and, however much we may desire to test the patient's hearing on the operating table immediately the fenestration has been made, movement of the head is most distressing for the surgeon during this manœuvre and full anæsthesia is desirable

Heavy premedication and infiltration up to the point of fenestration is satisfactory, with Pentothal intravenously when the actual fenestration begins

Both sides of the tragus are infiltrated down to the perichondrium with a 1 per cent Novocain Epinephrin, or similar solution This infiltration is continued along the anterior surface of the tragal cartilage and the cartilage of the meatus and, as dissection proceeds, over the anterior surface of the tympanic plate The skin incision is over the tragus, either over the edge or internal to it, to ensure the minimum visible scar, or in the fold between the tragus and the temporo mandibular articulation The incision is extended upwards and downwards and is about 1½ in long The skin is reflected off the cartilage of the tragus and blunt dissection is carried over the anterior surface of the cartilage of the meatus and the latter's attachment to the tympanic plate Further blunt dissection clears the bone of the anterior surface of the tympanic plate until the latter is exposed for ½ inch

This entire exposure occurs in the fascial plane of the anterior surface of the cartilage and tympanic plate No vessels, nerves or other structures of consequence are encountered The field is bloodless

The tissues anterior to this plane are retracted forward *en masse*, pushing the temporo mandibular articulation with it The attachment of the cartilage to the tympanic plate is defined and infiltrated

The second incision is now made through this attachment and through the underlying skin, thus opening into and revealing the divided lumen of the meatus itself which has been previously sterilized with spirit A rongeur of suitable size is now inserted into the bony meatus, to grasp and remove a large part of the tympanic plate and its investment of skin

I have no hesitation in sacrificing the meatal skin lining of the tympanic plate Its dissection is tedious and preservation pointless This tongue of skin is insignificant and would most probably slough in any case

## ILLUMINATION AND MAGNIFYING DEVICES

Up to the tympanomeatal flap procedure I use a binocular prismatic headlamp with interchangeable objective lenses, ranging from 4 to 8 dioptries The latter gives a working distance of 14 centimetres and about 2½ magnification I find these magnifications most adequate up



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## Fenestration of the Labyrinth .

middle ear now stand revealed A few drops of adrenalin are instilled into the tympanic cleft

The crucial landmarks which leap into view are

The promontory ,

the round window ,

the tendon of the stapedius, issuing from the eminentia pyramidalis and running horizontally forward to attach itself below the capitulum of the stapes ,

the stapes, whose anterior and posterior crura can be seen through the thin stapedial obdurator membrane ,

the long process of the incus, and its lenticular process attached to the capitulum of the stapes, and forming almost a right angle with the stapedial tendon

The crura of the stapes descend into the recess of the oval window where they become attached to the footplate of the stapes It is most important to realize and now can be clearly made out that the oval window is not in the same plane as the promontory, but in a deep recess

The chorda tympani can be observed in the upper part of the field running across the long process of the incus and disappearing behind the neck of the malleus I do not know of any procedure in which the surgeon is so generously provided with unmutilated landmarks

### TREPHINATION OF THE AMPULLA DOME REGION OF THE VESTIBULE (LEMPERT)

Although some emphasis is laid on fenestration of the cochlear vestibule in a latter part of this paper, the original object of this investigation was to discover a more rational approach to the classical fenestration site, namely the ampulla dome region of the vestibule This site has the greatest number, as well as the most consistent record of successes to its credit The transtympanic approach, as described, is the outcome

With the transtympanic approach, as thus far described, the ampulla dome region is still overhung by the lateral wall of the attic or epitympanic space This wall must now be removed with dental burrs The denuded bone of the meatus adjacent to the tympanic ring superiorly and posteriorly is thinned down until skeletonized and thin flakes of bone can be lifted away revealing the entire incus The long process of the incus guides the operator to the body and head of the incus With sharp pointed scissors the incudo-malleolar articulation is severed, as well as the attachment of the long process of the incus to the capitulum of the stapes The incus is now removed in its entirety and discarded There is no need to amputate the head of the malleus, as it does not obstruct the field in this approach

The ampulla of the lateral semicircular canal and the dome of the vestibule now lie clearly revealed and "square on" The facial nerve

attic and antrum. The results have been extremely good, thus far. Otologists wishing to gain experience in working with magnification and in the transtympanic approach, should not hesitate to give this method a trial in cases where they would perform the mastoid operation.

I would urge some preliminary practice on the cadaver to develop aptitude with the binocular magnifying device, and the dental machine. No gouges, chisels or mallet may be used.

### OTHER FENESTRATION SITES IN THE LABYRINTH RENDERED ACCESSIBLE BY THE TRANSTYMPANIC ROUTE

- A. Fenestration of the "Cochlear Vestibule".
- B. Removal of the footplate of the stapes.
- C. Fenestration of the Scala Tympani.

The surgeon is not limited to the upper part of the vestibule above the facial nerve. With the transtympanic approach the whole vestibule, as well as the scala tympani, is at his disposal.

Fenestration of sites other than the dome are still in the realm of experimental surgery. The next few years may establish their importance.

### THE PROMONTORY

The promontory covers two distinct portions of the labyrinth—vestibule and scala tympani. The lower portion of the promontory corresponds to the scala tympani, and is closed posteriorly by the round window, which is covered by the delicate secondary tympanic membrane.

The basal portion of the basilar membrane is attached laterally to the inner surface of the promontory, and medially to the edge of the basal portion of the lamina spiralis ossea. The basilar membrane sweeps back to be attached to the upper border (internal surface) of the round window, thus completely shutting off the basal portion of the scala tympani from the vestibule above. That part of the vestibule which lies above the basilar membrane and lamina spiralis ossea, I have termed the "cochlear vestibule". The scala vestibuli of the cochlea begins at its anterior and lower extremity.

The cochlear duct begins as the caecum vestibulare in the "cochlear vestibule", and lies on the upper surface of the basilar membrane and in close apposition laterally to the promontory wall.

In order that hearing be restored by fenestration the mobility of the perilymph of the vestibule (and the scala vestibuli) must be restored. This perilymph is continuous with that in the scala vestibuli of the cochlea. The latter communicates with the perilymph in the scala tympani through the helicotrema at the apex of the cochlea.

The membrane closing the round window must be functionally unimpaired.

# Fenestration of the Labyrinth

Removal of the promontory wall, without reference to such portions of the membranous labyrinth attached to its internal surface, either damages the basilar membrane and the cochlear duct, with consequent loss of function, or at best throws the basal coil of the scala tympani into immediate communication with the perilymph of vestibule. In the latter case, the auditory stimulus is not transmitted *via* the helicotrema—the entire cochlea is shortcircuited.

## FENESTRATION OF THE "COCHLEAR VESTIBULE"

Cases have been reported of short lived restoration of hearing after trephination of the promontory.

This dubious record appears to have discouraged further investigation to discover a fenestration site in this convenient region. When fenestrating the vestibule in the region of the promontory it is imperative that no invasion or penetration of the scala tympani occurs.

Clearly fenestration must be performed above the attachment of the basilar membrane, i.e. in the "Cochlear Vestibule". This is my site of choice and, when difficulties of instrumentation have been overcome, it may compete with the "dome" site for the following reasons:

- 1 Easy access
- 2 No ossicle is sacrificed
- 3 The attic wall is untouched
- 4 No raw bone surface is created requiring an epithelial covering
- 5 The fenestration is remote from the nerve supply—less vestibular disturbance
- 6 The thinnest part of the tympanic membrane—membrana tensa—covers the fenestration
- 7 The promontory is thin flat bone—minimal regenerative tendencies and danger of osteogenetic closure of fistula

## EXPOSURE OF THE "COCHLEAR VESTIBULE"

The transtympanic technique is carried through up to the completion of the tympanomeatal flap. The attic wall is left intact. The malleus is gently displaced forward until a space in front of the anterior crus of the stapes is cleared on top of the "shoulder of the promontory", which is parallel to and below a line continuous with the tendon of the stapedius. The fenestration should lie on, but not cross, the horizontal tangent of the upper curvature of the round window.

During dislocation forward of the malleus it will occasionally be observed that the lenticular process of the incus becomes detached from the capitulum of the stapes. It is of no consequence even if in addition, as I suspect, the processus gracilis of the malleus is fractured.

The point is that this fenestration demands neither the removal of an ossicle (incus) or of the attic wall.

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The promontory wall is thin—rather less than one millimetre in this region. This may be important in that regenerative tendencies in flat thin bone are less marked than in thicker bone as encountered over the ampullary dome region. The horizontal tangent to the upper curvature of the round window defines the limits of safety.

Fenestration above this line, and anterior to the anterior crus of the stapes, will avoid invasion of the scala tympani and damage to the cochlear duct and basilar membrane.

The safest site is the "shoulder of the promontory", where it dips inwards towards the oval window, at a point just in front of the anterior crus of the stapes.

The "cochlear vestibule" site is not accessible by the orthodox posterior approach.

### TECHNIQUE OF FENESTRATION

The burr is a diamond paste cylinder one and a half millimetres in diameter.

This cylinder, rotating at about 3000 revolutions per minute, is made to stroke the shoulder from behind forwards, gentle downward pressure being applied. Bone dust debris, and spicules, are removed by irrigation suction.

The shoulder is thinned down, spicules and endosteum are dealt with carefully; thin wafers of bone come away, usually with endosteum attached. The edges of the cavity are carefully smoothed and finished.

The operator may now close it with cartilage—derived from the already conveniently stripped tragus. This, according to Lempert, will prevent osteogenetic closure and post-operative labyrinthitis. Lempert's argument and records are convincing.

The tympanomeatal flap is replaced as described. The membrana tensa—thinnest portion of the tympanic membrane—covers the fenestration.

The "cochlear vestibule" is remote from the nerve supply to the ampulla, saccule and utricle. These nerves ramify in the dome of the vestibule to supply the respective parts of the labyrinth. Post-operative labyrinthine disturbances may, therefore, be expected to be less severe and more evanescent than when fenestration takes place immediately adjacent to these nerves at the ampulla and dome, as there is less liability to trauma. Such trauma may be thermal—due to the heat generated by the burrs, or actual injury.

Thirty-six labyrinths were dissected to verify the "cochlear vestibule" site for fenestration. I am deeply indebted to Professor R. A. Dart of the Department of Anatomy, Witwatersrand University, for assisting me in this work. Professor Dart placed at my disposal not only his vast experience, special knowledge and advice, but also the

# Fenestration of the Labyrinth

enormous resources and material of his department, as well as the services of the Technical Department headed by Mr E W Williams Without this co operation it would have been impossible to conduct and conclude this investigation

## REMOVAL OF THE FOOTPLATE OF THE STAPES

The oval window (with stapedial footplate) and upper portion of the promontory are part of the vestibule adjoining and directly continuous with the dome ampulla region The oval window should be the ideal fenestration site In practice this has not been confirmed With the transtympanic approach and the dissecting microscope removal of the stapedial footplate presents no special difficulties and can be done under perfect visual control

Eustachius in 1564 stated that the footplate adheres to the labyrinthine sac—presumably the saccule Whether this adhesion can always be demonstrated or not, damage to the membranous labyrinth is probably an important cause of failure where this operation is attempted "blind", i.e. with the posterior approach and without an operating microscope As the otosclerotic process is assumed to invade the footplate of the stapes, causing its fixation, the advisability of surgical interference in this region seems highly questionable

## THE SCALA TYMPANI AND ROUND WINDOW

To the best of my knowledge all fenestration procedures to date have been performed on the vestibular portion of the labyrinth, whose perilymph is continuous with that of the scala vestibuli of the cochlea It has been proved beyond any doubt that fenestration of the vestibule will only succeed in restoring hearing if the membrane closing the round window (scala tympani) is functionally unimpaired With the transtympanic approach the scala tympani becomes accessible for fenestration

Cases are rejected that show a low cochlear nerve function reserve as tested by bone conduction with the Audiometer Are these cases true nerve deafness? Histological evidence of degenerative changes in the nerve endings of the organ of Corti in such cases are meagre and unconvincing Could not an alternative hypothesis be considered—compatible with the theory that perilymph mobility determines hearing function? I suggest that instead of assuming without adequate evidence that nerve degeneration has occurred, we assume that through perilymph impedance the vibration simply does not reach the upper region of the cochlea that the latter thus receives no stimulus, and does not respond to sounds in the upper register, despite the fact that the nerve endings in the spiral organ are functionally unimpaired Closure of the round window could produce such a situation

Fenestration of the scala tympani, alone or in addition to vestibular fenestration, may prove effectual in such cases of profound mixed deafness. These procedures involving the scala tympani and round window are yet strictly in the experimental stage. They may open up a long vista in labyrinthine surgery. Cases hitherto considered borderline or unsuitable in view of age or so-called superadded nerve deafness may come within the scope of fenestration, or double fenestration.

Is stapedial fixation a constant in every case of otosclerosis? Closure of the round window would produce the same symptoms. It may precede, accompany or occur independently of stapedial fixation. Incidentally the fixation or mobility of the stapes can be checked at the operation. Round window closure is not so easy to determine. A test for this is imperative. Lack of patency may explain why some cases of otosclerosis are not improved by fenestration of the vestibular labyrinth. Fenestration of the scala tympani may restore perilymph mobility in such cases. The site for fenestration of the scala tympani must lie below the attachment of the basilar membrane. The scala tympani of the cochlea is much larger than the scala vestibuli. If a tangent be drawn  $30^\circ$  to the horizontal touching the upper curvature of the fossula of the round window, the site of fenestration lies below and behind this line, and between it and the lower curvature of the round window. The attachment of the basilar membrane within the promontory wall lies above and in front of this area.

### TINNITUS AND VERTIGO

T. E. Cawthorne and A. J. M. Wright have recently published their operative technique for the relief of labyrinthine disturbances. Cawthorne's operation would be easier by the transtympanic route. Wright injects alcohol into the oval window through the intact drum. Those otologists who prefer to do this by an open method and under visual control will find the transtympanic route reveals this region with great clarity. Lempert reports that successful fenestration abolishes tinnitus. Intolerable tinnitus must, therefore, be considered an indication for operation.

The scope of this work is vast ; technical difficulties are formidable. No one alone could hope to cope with its development. This is a task of international magnitude ; nor should anyone imagine that a few weeks tuition and perhaps seeing these operations done will confer any skill whatsoever. Such an attitude will only bring this work into discredit.

There is only one way to begin and for that there is opportunity in every large centre—on the cadaver. No opportunity should be missed of repeatedly going back to the cadaver so that when the decision of operating on cases is taken most of the imponderables associated with this type of surgery have been encountered. Let there be no rush to various

## Fenestration of the Labyrinth

centres but rather a laying down of solid foundations—in the dissecting room—at home.

I hope to present clinical records in eighteen months or after a lapse of time sufficient to allow for dispassionate evaluation.

In the meantime I present this mixture of practice, experience, and theory, not prematurely, but for a definite purpose—that no time be lost in the development of labyrinthine surgery. If my observations have stimulated further investigation and, above all, a large recruitment of my colleagues—who for various reasons may have held aloof—into the field of labyrinthine surgery, the purpose of this paper will have been amply achieved.

Collectively a few years will crystallize labyrinthine technique, where a lifetime will leave the labour unfinished for one who works alone.



# CLINICAL RECORD

## PERFORATION OF THE AORTA BY A FOREIGN BODY IN THE ŒSOPHAGUS

### CASE REPORT AND REVIEW OF THE LITERATURE

By H. J. BARRIE and V. TOWNROW (Sheffield)

PERFORATION of the aorta by a swallowed foreign body is not very rare, even in these days when radiography and œsophagoscopy are so widely available. The clinical history is very uniform and has enough features of interest to make it worth while reviewing the reported cases and describing an additional one.

#### Case Report

A woman aged 60 was eating fried plaice, when she felt a sharp scratching pain down the mid-line of her back. It shortly recurred and became constant, tending to radiate round the right side to the breast. The pain was increased on swallowing fluids and it became excruciating when an attempt was made to swallow bread. A barium swallow and radiograph revealed nothing abnormal and the pain diminished and later disappeared.

Seven days after the original accident she felt a very violent bursting pain and then vomited a quart of mixed bright red and dark red blood. The next day she was admitted to hospital. She was tender to deep palpation over the 7th dorsal vertebra, her pulse was 94 and temperature  $97\cdot2^{\circ}$ . She did not look ill. The day after admission she suddenly vomited a large quantity of blood and died.

#### Summary of Autopsy Report. P.M. 157/43

Very pale stout woman. Pharynx full of dark blood. Oesophagus contracted and empty. In the anterior wall of the œsophagus, at the level of the lower part of the aortic arch, was a round perforation 0·2 cm. diameter, with ragged, discoloured edges. The perforation led directly into the aorta. At this point the œsophagus was closely attached to the arch by its normal fibrous tissue connections and no space had formed there from œdema, inflammation or hæmorrhage. The track of the perforation itself was full of blood clot. The stomach was full of clotted blood. The intestines contained tarry black blood at intervals; they were searched carefully but no foreign body was discovered. The bronchi contained bubbly, dark red blood. No relevant changes in other organs.

#### Discussion

80 similar cases have been reported in the literature and, although we have been unable to consult each original article, we have collected the details of enough to show that the clinical course is very uniform.

# Clinical Record

Owing to the dramatic nature of these accidents and the relative ease of reporting them, the number of recorded cases must be a better index of their frequency than is the case with most illnesses. For the same reason the frequency relative to other complications of swallowed foreign bodies will be unnaturally high. Adelmann (1867) reviewed 314 published reports of foreign bodies in the œsophagus, among which there were 14 cases of perforation of the aorta.

It is noticeable, in the literature, that even the most experienced surgeons rarely saw more than one case. Table 1 shows the distribution in the decades.

TABLE 1  
DISTRIBUTION OF REPORTED CASES IN DECADES

Decades	No. of cases	Decades	No. of cases
1840-49	3	1900-1909	10
1850-59	5	1910-1919	19
1860-69	6	1920-1929	5
1870-79	6	1930-1939	6
1880-89	4	1940	3
1890-99	7		1

of the past century of 74 of the published cases, and it cannot be said that the numbers show any decline since the introduction of radiography.

The object responsible for the perforation was cited in 39 cases as follows:

Unspecified bones 15, fish bones 8, rabbit bones 2, chicken bones 1, coins 4, safety pins 3, dentures 2, collar stud 1, pin 1, needle 1 and wire 1.

A reflection on table manners is afforded by the fact that three times as many men were affected as women.

The blood vessel most commonly injured by perforation of the œsophagus is the aorta. Schlemmer (1929) collected 51 cases of perforation of the aorta, 2 of the other vessels in the thorax and 29 of vessels in the neck.

The clinical features of perforation of the aorta have been well described by Chiari (1914). He stressed the initial discomfort on swallowing the foreign body, frequently followed by a symptom-free interval of several days and then by the fatal hæmorrhage, the latter almost invariably preceded by a signal hæmorrhage. His description is borne out by a study of Table 2. There were 18 observations on pain as a symptom of which 7 referred to pain as being constant and 11 as being absent or temporary. Most of the cases with temporary pain had a recurrence of this symptom shortly before death. In all, except one, of these 18 well documented cases there was a signal hæmorrhage before the main fatal one, preceding it by a period averaging one day and ranging from two hours to three days.

No satisfactory explanation for this phenomenon has ever been put forward. The first hæmorrhage apparently comes from the aorta and then for some reason stops. This cessation is not due to fall in blood pressure for the bleeding is rarely severe enough to cause this. Krause (1897) thought that the initial hæmorrhage was stopped by the formation of a perivascular clot and that progressive sepsis softened the clot. In many of the cases however there was no evidence of sepsis and we consider it unlikely that a thrombus

TABLE 2.

Author	Patient	Foreign body	Pain	Signal hemorrhage and its interval before main hemorrhage	Site of perforation	Presence of sepsis	Interval between accident and death
Gardener and Coats, 1887	Man aged 63	Fish bone	Temporary	Yes, 1 day	—	Yes	9 days
Ananiasoff, 1894	—	Fish bone	—	—	Thoracic aorta	—	9 days
Owen, 1903	Woman aged 53	Pin	Constant	Yes, 12 hrs	—	None	7 days
Oliver, 1909	Woman aged 40	Fish bone	Temporary	Yes, 1 day	Thoracic aorta	None	11 days
Lovett 1909	Boy aged 8	Halfpenny	—	—	Arch	—	—
Grey Turner, 1910	Child aged 4	Halfpenny	None	Yes, 3 days	Arch	No	1 yr 10 m.
Grey Turner, 1910	Man aged 54	Rabbit bone	—	—	—	Yes	5 days
Grey Turner, 1910	Man aged 40	Rabbit bone	—	—	—	No	7 days
Grey Turner, 1910	Man aged 22	Hake bone	—	—	—	No	6 days
Taylor, 1913	Woman aged 22	Fish bone	Constant	Yes, 1 day	Arch	Yes	—
Chari, 1914	Woman aged 28	Safety pin	Temporary	Yes, 12 hrs	Thoracic aorta	Yes	6 days
Chari, 1914	Man aged 47	Bone	Constant	Yes, 1 day	Arch	Yes	—
Goffe, 1915	Baby aged 10 m	Safety pin	Temporary	Yes, 12 hrs	Arch	No	1 weeks
Kaempfer, 1917	Baby aged 8 m	Collar stud	None	Yes, 2 hrs	Arch	Yes	13 days
Seiffert, 1919	Woman aged 48	Bone	Constant	Yes, 1 day	Arch	Yes	11 days
Swan, 1930	Baby 10/12 m	Wire	—	Yes, 1 day	—	Yes	—
Tueter, 1932	Baby aged 7 m	Safety pin	—	—	Arch	—	—
Cases quoted by							
Adelmann, 1867	Man	Bone	—	—	—	—	7 days
Bert	Man aged 25	Bone	—	—	—	—	8 days
Mienne, 1850	Man aged 26	Bone	—	—	—	Yes	6 days
Fabrice, 1864	Man aged 54	Bone	—	—	—	—	11 days
Sarteson	Woman	Bone	—	—	1½ in above diaphragm	—	6 days
Laidlaw							

# Clinical Record

Wagret	Man	Bone	—	—	—	Descending aorta	—	6 weeks 5 minutes 6 days 10 days 12 days 10 days 14 days — 1 day 7 days 5 days 12 days 7 days — 8 days 1 day 8 days
Lamenain	Man	Bone	—	—	—	—	—	—
Dubreuil	Man	Bone	—	—	—	—	—	—
Laurncin, 1824	Man	Bone	—	—	—	—	—	—
Auvert, 1848	Woman aged 20	Fish bone	—	—	—	—	—	—
Duncan, 1844	Man	Denture	—	—	—	—	—	—
Martin, 1824	Man	6 franc piece	—	—	—	—	—	—
Dononvilliers, 1856	Man	5 franc piece	—	—	—	—	—	—
Colles, 1855	Man aged 56	Bone	Constant	—	—	—	—	—
Hünemann, 1934	Man aged 26	Denture	Temporary	Yes, 12 hrs	—	—	No	7 days 5 days
Dreack, 1934	Man aged 49	Bone	—	—	—	—	—	—
Decoult and Omez 1939	Man aged 41	Chicken bone	None	Yes, 3 days	—	Arch	None	12 days
Szabó, 1938	Woman aged 40	Bone splinter	Constant	Yes	—	Arch	Yes	7 days
Jones, 1940	Man aged 28	Needle	Constant	None	—	Arch	None	—
Bank, 1943	Girl aged 12	Fish bone	Temporary	Yes, 1 day	—	Thoracic aorta	—	8 days
Dick and Nevill, 1946	Man	Bone	Temporary	Yes, 12 hrs	—	Arch	Yes	1 day
Barrie and Townrow 1946	Woman	Fish bone	Temporary	Yes, 24 hrs	—	Arch	No	8 days

(A dash means no observation available)

Martin, Bégin 1832, Auvert de Moscon 1850, Bégin 1832, Révolat, Lavacherie 1848, Spry and Farquharson 1869, Huques 1870, Ramskull 1871, Bradley 1868, Théron 1862, Shetter 1878, Bousquet 1877, Aschenbon 1877, Haurmin 1825

Additional 14 cases cited by Poulet (1880)

Additional 28 cases cited by Schiemmer (1920)  
 Aras 1862, Balacescu 1904, Blandien 1906, Braasch 1886 (two cases), Bulwert 1901, Dietrichs 1894, Durham 1904, Feldham 1919, Gebser 1865, v Hacker 1913, Knaggs 1908, Levy 1897, Martin 1918, Neumeyer 1905, Nevil 1897, Pienazack 1902, Plant 1921, Srebrny 1919, Symes Clark 1884, Viannay 1910, Vogel 1921, Waller 1910, Weyrauch 1893 (two cases), Williams 1892, Mayr 1920, Milligan 1912.

could oppose the blood pressure in the aorta. It is possible that the initial perforation is closed by a temporary spasm of the arterial wall.

The time interval between accident and death was stated in 37 cases. These fell into two natural groups according to whether the perforation was caused by a sharp or blunt object. One sharp object, a bone, perforated the aorta within 5 minutes of swallowing it and one took six weeks. These were, however, exceptional cases and the remainder, on an average, took 8 days, with a standard variation of plus or minus 3-38.

Perforation is probably caused by constant pressure, aided by contractions of the œsophagus and pulsation of the aorta. Sepsis does not appear to play an important part if the time between accident and death be any criterion. In 9 cases where sepsis was stated to be present the average interval was 7 days, and in 7 cases where it was absent the average interval was 8 days.

The five blunt objects showed great variation in the time they took to erode the aorta, ranging from 14 days to 1 year 10 months.

Treatment of the condition other than on prophylactic lines must remain an academic question. A knowledge of its occurrence can serve only to underline the need for caution in dealing with the patient who has swallowed a foreign body. *Loss of pain should not produce complacency. For practical purposes, however, it may be said that after a lapse of two weeks a sharp foreign body is unlikely to show its presence by puncturing the aorta.*

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## ABSTRACTS

### EAR

*Some Remarks on Vestibular Nystagmus* A DE KLEY, *Confinia Neurologia Separatum* 11, Fasc 5

The first part of this paper is devoted to experimental work on the reflex arc of vestibular nystagmus. It is pointed out that little is known of the cause of the quick component in vestibular nystagmus but that experimental work has established a more extensive knowledge of the site of origin. Normal vestibular nystagmus can be elicited —

- (a) After the removal of the cerebral hemisphere
- (b) After removal of the cerebellum
- (c) After a section of the brain just anterior to the abducens nuclei, whereby the nuclei of the oculomotor and trochlear nerves are put out of function, and
- (d) After a section of the medulla taken just behind the vestibular nuclei

Thus it is apparent that a small reflex arc suffices for vestibular nystagmus with a normal slow and quick phase. peripheral labyrinth, vestibular nuclear area, abducens nucleus, abducens nerve and external rectus muscle

This small arc is not only applicable to animals but also to the human as proved by experiments on an anencephalous monster which was devoid of cerebral hemisphere, cerebellum, mid brain (including the oculomotor and trochlear nuclei) and in which all the ocular muscles were absent with the exception of the external recti. This experiment, while establishing that only a small arc is essential, did not rule out the possibility that other nuclei of the brain or other influences do not play a part.

A series of experiments were conducted to investigate the influence of external stimuli on nystagmus. These showed that stimulation of the nasal mucous membrane can cause some acceleration of the nystagmus whereas a stronger stimulation will irritate the vestibular system until ultimately complete paralysis of nystagmus may occur.

The second part of the paper is devoted to a few observations showing the application of experimental work on the clinical picture. Attention is drawn to the possibility of wrong conclusions being drawn from the caloric test where only cold water is used. It has been found clinically that the cold caloric test may give an apparent reaction in cases where there is known to be complete loss of labyrinthine function. The explanation is that there is a latent tendency to nystagmus arising from the opposite labyrinth which has been made manifest by the sensory stimulus of cold in the functionless side. In such cases a similar reaction would also be produced by warmth but the response would be a nystagmus to the opposite side (i.e. the response which might be expected from the cold caloric test). This has been confirmed by animal experiments.

Experimental investigation has also elicited a cause for a second type of case hitherto an enigma. Sudden vertigo may occur in some patients after bringing

## Abstracts

the head first backwards and then to one side. Experimentally it has been proved that this movement reduces the flow of the vertebral artery on the same side owing to pressure in its course between the atlas and the skull. If the auditory artery arises directly from the vertebral in these cases the result is a complete occlusion of the blood supply (the auditory artery being an end artery). The resultant anæmia of the labyrinth gives rise to vertigo.

J. GILROY GLASS.

*Über Die Gehorsverbesserung Mit Hörapparaten.* URPO SIIRALA. *Acta Oto-Laryngologica*, March 1st-April 4th, 1945, xxxiii.

The author examined 685 persons who were permanently hard of hearing and attempted to classify them according to the improvement received from hearing apparatus.

His conclusions coincide with the impressions generally held by otologists and there is little new in the paper, but a useful task has been performed by putting these impressions on a sound scientific basis.

He notes that in general the older the patient the less tolerant of a hearing aid he will be.

G. H. BATEMAN.

*Experimental Histological Studies on the Labyrinth.* S. H. MYGIND, H. C. ANDERSEN, J. ARNVIG. *Acta Oto-Laryngologica*, July 1st-August 8th, 1945, xxxiii.

In volume xxxiii S. H. Mygind and his co-workers have published a series of six articles on experimental histological studies of the labyrinth. They describe a method of intravital staining and compare the results obtained with those obtained with postmortem staining. Differences are noted and discussed. Changes in the labyrinth caused by injection of histamine, adrenaline and other chemicals are studied. The whole series is well illustrated with microphotographs, and should be of great interest to the research worker in this line but is highly technical and most clinicians will have to await its interpretation before the results can be applied to clinical otology.

G. H. BATEMAN.

*Otitis Media caused by Swimming.* JOHN CHR. NIELSEN. *Acta Oto-Laryngologica*, February, 1945, xxxiii.

The author has carried out bacteriological studies on cases of bathing otitis occurring in 1941 and 1943. He concludes that bathing otitis is an endogenous infection and impure bath water has no etiological significance. This agrees with the opinion held by most otologists.

G. H. BATEMAN.

*Hearing. Some orientating remarks on tuning forks and audiometer and on the registration of defects of hearing.* S. H. MYGIND. *Acta Oto-Laryngologica*, February, 1945, xxxiii.

This very interesting paper provides an explanation for the apparent contradiction between tuning fork and audiometer tests in middle-ear deafness.

The author quotes a typical case of otosclerosis and obstructive deafness

# Nose

due to wax and gives the tuning fork tests and audiograms. The reason for the discrepancy is the fact that subjective loudness levels at the various frequencies do not vary equally with the change in physical intensity as expressed by decibels. The author then converts the audiograms into loudness audiograms with the subjective unit the "son" as the ordinate. This shows that in obstructive deafness the greatest loss is at the low tone end and not at the high tone end, as is suggested by the audiogram expressed in decibels.

He concludes that for complete examination of the auditory function tuning forks, monochord and audiometer are all desirable.

G H BATEMAN.

## NOSE

*Treatment of Frontal Sinusitis with Beck's Puncture* A JORGENSEN and K. R. MELGAARD *Acta Oto Laryngologica*, February, 1945, xxviii

The authors describe seven cases of frontal sinusitis treated by puncture through the anterior wall. This is the method described by Beck in 1933 when the cannula is left in situ for several days to permit of drainage and medication of the sinus mucosa. This seems a promising method of treatment which is so far not adequately recognized in this country.

G H BATEMAN

*The Roentgen Treatment of Vasomotor Rhinitis* AXEL RENANDER *Acta Oto Laryngologica*, February, 1945, xxxiii

This paper gives an analysis of 226 cases of vasomotor rhinitis treated during three years, 1938-1941. The results of this treatment appear to be extremely promising as only ten per cent were not improved and sixty seven per cent report complete freedom from symptoms.

The treatment consists of three treatments of 150 r on the sinuses and nose with one or two days interval between treatments. The authors give inadequate descriptions of the technique as it is not clear in the text how many fields were used, or where the dose of 150 r was measured. A large field was being irradiated and therefore where the measurement was taken is of considerable importance.

No bad results from the treatment are reported.

G H BATEMAN

*Local treatment with Sulfathiazole in Sinusitis* PETER BERDAL *Acta Oto Laryngologica*, May 1st-June 30th, 1945 xxxviii

These investigations consisted of 42 cases of maxillary sinusitis subjected to sulfathiazole treatment and 48 cases treated similarly with the omission of the introduction of sulfathiazole into the antrum. The results of the investigations are summarized as follows:

1. It could not be proved that the sulfathiazole treatment occasioned any reduction of the number of antrum punctures.

2. Nor that the sulfathiazole treatment reduced the number of operative cases.

3. The use of sulfathiazole in a 10 per cent suspension in the maxillary cavity in sinusitis thus seems without any therapeutic effect.



## Abstracts

4. The sulfathiazole treatment is of equally little avail whatever the pathogenic microbes be that are present.

5. In the said form the sulfathiazole involves a state of irritation of the mucous membrane in the maxillary cavity, though this seems to be moderate.

G. H. BATEMAN.

*Orbital Complications following operations on Paranasal Sinuses.*  
ERIK GODTFREDSSEN. *Acta Oto-Laryngologica*, May 1st-June 30th, 1946, xxxiii.

Examination of the literature shows comparatively few reports of orbital complications following operations of the sinuses. The author thinks that it is probably much more common than the literature would suggest as he was able to trace 8 cases in his own clinic in a six year period.

He has reviewed his own 8 cases and 42 reported in the literature from 1902 onwards. It seems that the complications are much commoner after intranasal ethmoid than any other operations. Furthermore the symptoms after maxillary operations are likely to be transitory whereas the majority were permanent after ethmoid operations. He therefore suggests that active surgical treatment of the complications should be instituted in those cases arising after ethmoid operations. He gives some indications for active surgical treatment.

G. H. BATEMAN.

*Local Treatment of Maxillary Sinusitis with Alfazol.* HELMER RASMUSSEN.  
*Acta Oto-Laryngologica*, September 1st-December 31st, 1945, xxxiii.

The author has treated 58 cases of maxillary sinusitis with injections into the sinus of alfazol and has, at the same time, had 59 control cases. The treatment of both series was identical except that the alfazol was omitted in the control group.

No improvement in the results with alfazol was noticed and no benefit seemed to be derived from local chemotherapy.

Alfazol is a proprietary sulfanilamide derivative.

G. H. BATEMAN.

## TONSILS

*Tonsillectomy: General or Local Anæsthesia.* KARSTEN KETTEL. *Acta Oto-Laryngologica*, July 1st-August 30th, 1945, xxxiii.

This is an interesting report on 500 cases of tonsillectomy under general anæsthesia. The results in these cases compare favourably with cases done under local anæsthesia in other Danish hospitals. The author concludes that general anæsthesia is the method of choice for tonsillectomy in adults. This is particularly interesting when it is remembered that very recently in this stronghold of general anæsthesia, in the section of Anæsthetics at the Royal Society of Medicine, local anæsthesia was advocated for tonsillectomy in adults on the very grounds that this author advocates general anæsthesia:

Less danger.

Fewer complications.

Less anxiety to patient and surgeon.

Less post-operative pain.

G. H. BATEMAN.

## Miscellaneous

*Cases of Familial Œsophagus Stricture.* SIGFRID ABERG. *Acta Oto-Laryngologica*, May 1st-June 30th, 1945, xxxiii.

The author was able to examine members of three generations of one family in which cases of simple stricture of the Œsophagus occurred. The symptoms were similar in all cases and the three subjected to Œsophagoscopy showed similar simple strictures. In all cases the symptoms appeared around the age of forty. There seems no doubt that these strictures were due to a congenital lesion.

No other cases of similar familial strictures can be found in the examination of the literature.

G. H. BATEMAN.

### MISCELLANEOUS.

*Osteomyelitis Necroticans Faciei.* HELMER RASMUSSEN. *Acta Oto-Laryngologica*, May 1st-June 30th, 1945, xxxiii.

Two cases are reported both of which terminated fatally. Thirty-three similar cases have also been collected from the literature. The author can find no cause for the lesion and histological examination showed simple granulation tissue. He considers this to be a disease sui generis.

G. H. BATEMAN.

*Complications in the Ear, Nose and Throat in Infectious Mononucleosis.* ELMAR BERG. *Acta Oto-Laryngologica*, September 1st-December 31st, 1945, xxxiii.

The case histories of 550 patients suffering from infectious mononucleosis were examined and it was found that 187 suffered from ear, nose and throat complications.

As a result of this investigation it appears that the lymphoid tissue in the upper respiratory tract is damaged by the original disease and thus made susceptible to secondary infections.

The authors suggest that local prophylactic treatment should be instituted to the upper respiratory tract but that the incidence of the complications is spread over so long a time that general chemotherapy is not indicated.

G. H. BATEMAN.



# The Journal of Laryngology and Otology

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## CONTRIBUTIONS TO FUNCTIONAL PATHOLOGY—IV.

### CLINICAL NOTES ON PROGRESSIVE CONGENITAL DEAFNESS

By F. KOBRAK (London)

FOLLOWING Politzer's description of otosclerosis and Manasse's of progressive cochlear deafness as two separate pathological-anatomical entities, otology of the first decades of the century referred the anatomical differentiation more or less to the associated clinical phenomena. Manasse however shook the dualistic conception of the two types by his own research work, in the early '20s. Manasse found, on the one hand, cases in which one ear showed histologically typical nervous degeneration, the other otosclerotic osseous changes. He found, on the other hand, that otosclerotic osseous changes need not be localized only *loco typico* round the oval window but can be dispersed over wider areas of the petrous bone. This was confirmed by Crowe and others. It was A. Gray (1934) who first stressed the pathological-anatomical point that primary cochlear degeneration is of essential significance with otosclerosis [*vide* Appendix A]. A further advance is marked by Lange's findings (*Zeit. Hals. etc. Heilk.* 25, 1, 1930), that not only fully developed stages but also pre-stages of otosclerotic changes are essential in the genesis of otosclerosis. This was further followed up, especially with regard to the blue mantles of the vessels, by M. Weber upon microscopic studies with polarized light.

The extension to, even most frequent localization of, otosclerotic changes and pre-otosclerotic stages round the semicircular canals (M. Weber) seems to explain the not infrequent occurrence of vertigo

with otosclerosis. It explains furthermore the writer's observations on a fairly large scale that *objective* signs of *vestibular* participation in *otosclerosis* are, to say the least, frequently encountered [Record I on vestibular signs with otosclerosis and with progressive cochlear deafness].

Otosclerotic osseous changes were discussed as a sign of premature senescence (—interpreted on a similar line by Siebenmann some 40 years ago !—), by O. Mayer, M. Meyer, and F. R. Nager (1933). Only, as M. Weber puts it, "when the small vessels are growing narrow, even obliterating",—normally with older people—, "signs of activity are found round the vessels characterized by specific structural changes". The following conclusion is justified: otosclerotic changes of normal, or abnormally premature, senescence, which involve ischæmia in the bone, are unlikely to leave the blood supply in the receptory organ unaltered. We should therefore expect *ischæmic cochlear degeneration* already with the earliest and even pre-stages of otosclerosis, and we could regard Gray's primary cochlear degeneration as pseudo-primary.

*Genetics.* The factor of secondary ischæmic changes in the organ of Corti upon primary otosclerotic changes is not only a problem concerning the individual case. It becomes also a problem of genetic significance, as soon as ischæmic changes become a permanent factor by "mutation" a pathological gene of *diminished resistance*. That the latter is the real cause of progressive cochlear deafness, conspicuous at least in a majority of cases, is not infrequently shown with progressive deafness which originates from, e.g., an influenza quite innocuous to the internal ear of most people, or by a family case with mother's cochlear deafness following diabetes in the early 50's and daughter's deafness following diphtheria (without otitis media), at the age of 13.

Two forms of "*Primordial Otosclerosis*" are suggested:

1. Otosclerotic osseous changes without secondary lesion of the organ of Corti.

2. Mixed forms of otosclerotic osseous changes and cochlear degeneration.

Three ideal types of genetic purity—or rather, at most, of pseudo-purity—emerge out of the primordial form (2) by genetic splitting up ("*Aufspaltung*", Mendelism), namely:

(2a)=(1). Otosclerosis—apparently—free from cochlear involvement,

(2b): classical progressive cochlear deafness where—so far!—no otosclerotic or pre-otosclerotic osseous changes have been noted,

(2c): progressive cochlear deafness, where otosclerotic osseous changes are suspected upon objectively abnormal vestibular behaviour [*vide* Record I].

The Primordial form (2) and the splitting up of the primordial form

## Contributions to Functional Pathology—IV

would provide a fairly satisfactory explanation for two still *unsolved*, clinical *problems*

(A) Familial differences in the types of congenital deafness with mother and child, occasionally beyond any doubt encountered [Record II]

(B) Differences between right and left ear in the same individual [Record III]

With regard to vestibular changes in otosclerosis, it is of genetic significance that typical attacks of vestibular vertigo are found in the family history of otosclerotics, more frequently than would be expected in an unselected cross section of non otosclerotic cases [Record IV]

*Applied Physiology* The different behaviour of the so-called bone conduction plays an important part in the discrimination between the two types of progressive congenital deafness. Only the former examination by tuning forks, less accurate as a test of auditory sensitivity (*J Laryng and Otol*, lx, 5) than audiometry, allows a smooth diagnosis and avoids conflicts of differential diagnosis. The diagnosis by tuning fork tests, with Schwabach and Rinne negative, reading "cochlear deafness with middle ear catarrh", is certainly wrong when there is not the slightest sign of any middle ear catarrh. Cases of "middle ear inefficiency", or dys efficiency, described by the writer (*Practica Otolaryngol*, 1938, I, 5), are concerned here.

With reference to the negative Rinne in cases of cochlear deafness we have to consider that, apart from anatomical, e.g., otosclerotic ankylostapedial changes at the middle ear *osteoankylosis* stapedial otosclerosis with "*morphological negative Rinne*", the negative Rinne can be caused by physiological changes of the middle ear. The latter are, with high probability, abnormal activities of the tympanic muscles *spasmoankylosis* stapedial otosclerosis with "*physiological negative Rinne*". The magnitude of the physiological negative Rinne cannot be exactly distinguished from that of the "total" (physiological + morphological) negative Rinne, but it can be approximately estimated by comparing fork steppage tests and audiometric Rinne figures, such as writer suggested (*J Laryng and Otol*, 1940, lv, 9) and has confirmed by comparison with recent cases. In any case, as long as there is no gross ossification at the oval window, the physiological rate of the "total" negative Rinne is important. The possibly high extent of abnormal activities in the tympanic muscles, associated with physiological negative Rinne in otosclerosis, is explained in Appendix D (2). The conditions of the physiological negative Rinne were illustrated as activities of the tympanic muscles by referring the figures of the original Rinne to those of the provocative Rinne (*J Laryng and Otol*, lx, 9, Note 7). Records Va and Vb are examples of a pure physiological

negative Rinne in cochlear deafness, and of physiological negative Rinne traceable in its superposition on morphological changes with otosclerosis.

In particular, from the clinical point of view, we have to bear in mind :

The basis of the physiological negative Rinne, that is, the abnormal activities of the tympanic muscles are a phenomenon *common to both* main types of congenital deafness.

*Symptomatology.* The division of *pathogenetic* from contributory factors which may be called "*nosoplastic*" is suggested with due regard to the combined, but not basically interdependent, occurrence of pathogenetic and nosoplastic conditions. The division is suggested not only for scientific reasons, but for practical purpose: "*Nosoplastic*" conditions are to some degree remediable; pathogenetic are not. The morphological,—pathogenetic,—factors are specific with regard to congenital deafness, they are the specific hereditary "*genes*", morphologically unalterable (except by genetic "*mutation*"). The physiological and psychological—nosoplastic—factors however are not intrinsically specific with regard to congenital deafness, they often are also hereditary, but they are variable. Part of the physiological factors is environmental, e.g., climate, food, occupation. Several authors have tried to produce otosclerotic osseous changes in animal experiments, e.g., by keeping the animal under subnormal or supernormal doses of vitamins: the osseous changes are similar to otosclerosis, but not really comparable on histological examination. Evidently, vitamin abnormalities, like metabolistic abnormalities, can play a contributory rôle as a nosoplastic factor, but they fail to produce specific pathogenetic changes, they are unable to produce the indispensable factor of pathogenetic constitution, which is due to pathological "*mutation*".

Even symptoms which the otologist regards as significant for the diagnosis of otosclerosis, such as ample waxless meatus, abnormal patency of the Eustachian tube, are specific though they be only nosoplastic, but not pathogenetic, even if the idea of local interrelation between calcium and fat metabolism were to be adopted.

One nosoplastic factor is of outstanding significance: the associated reflex activities of the tympanic muscles. They are suspected of being closely related to the phenomenon, that the *stage of clinical manifestation* is on the average connected with a percentage of decibel loss which is definitely less with progressive cochlear deafness than with otosclerosis [*vide* Record XI, table I, and Appendix B].

The nosoplastic factor of the activities of the tympanic muscles can become of special importance with reference to the *tonus* in the tympanic muscles. The *basic* features of this tonus are as follows:

The reflex activities of the tympanic muscles are on the one hand

## Contributions to Functional Pathology—IV

dependent on the normal or pathological stimulation of the VIIIth nerve, which is associated with the absence or presence of "specific" pathogenetic factors in the nervous tissue; they are also affected by an individual excitability which is "unspecific" and, so, not necessarily connected with the genetic conditions of progressive congenital deafness. This individual excitability is the effect of *basic tonus* conditions, of:

(a) vestibulo-tonus,

(b) vago-tonus,

(c) psycho-tonus.

(a) The vestibular tonus of the tympanic muscles is common to, but must be different in, the two main forms of progressive congenital deafness. The difference is due to the fact that the vestibular changes are more frequent and greater in otosclerosis than in progressive cochlear deafness [Record I].

(b) The individual vago-tonus is variable, and independent of the specific changes of the cochlear nerve, just as the knee jerk varies without any central lesion.

Apart from such vagotonic influences which are quite independent of otosclerotic conditions, some vagotonic influences are more or less associated with certain basic factors of metabolism (calcium, phosphorus), which are very near to, or possibly even overlap, the zone of specific influence of general otosclerotic conditions, and, so, often seem to play not only clinically, a contributory, but a striking part in the manifestation of otosclerosis (pregnancy).

(c) The psycho-tonus (auditory concentration and attention), of course, overlaps at least with (b) owing to the common relationship to the endocrine system. There are two different psychic types of otosclerosis, the torpid and the erratic irritable type (*Beitr. Anat. Physiol. etc. Ohr.* 1924, XX). In the torpid type the disease takes a more even course, whereas the course of the erratic type seems to be more variable, obviously more exposed to spasmophile (vagotonic) conditions.

### Mixed Pathogenetic—Nosoplastic Factors

(A) The *Pathogenetic Part of Nosoplastic Factors*.

Minor disturbance of the tympanic muscular reflex plays only a contributory rôle in abnormal hearing. But, when, either by highly abnormal irritability of the VIIIth nerve or when by hypernormal basic tonus, spastic muscular activities are caused, the muscular reflex becomes a factor of importance, for example in patients of the "spasmophile" vagotonic constitution. Then, labyrinthine pressure is enhanced (*Roy. Soc. Med. Sect. Otol., March, 1942*). The latter evokes a fresh irritation in the receptory organ. This involves new muscular spasm.



The "nervous vicious circle" is closed [*vide* "periosteal vicious circle" sub Appendix D].\*

(B) The *Nosoplastic Part of Pathogenetic Factors*.

It depends on the site at which the nervous or osseous changes come about. The site is to some degree a matter of chance and not subject to rigid genetic laws. Thus, osseous otosclerotic and nervous cochlear changes, as far as they are not pre-destined by conditions of locally different sensitivity (*J. Laryng. and Otol.*, 1944, lix, 9), are apt to produce.

*Different Types of Otosclerosis or Progressive Cochlear Deafness.*

Apart from classical otosclerotic changes at the stapes (ankylo-stapedial *classical otosclerosis* = "*c.o.*") and from changes around the semicircular canals, osseous changes can be located around the cochlea. The latter produce, in the one hand, according to higher vulnerability of individual sites of the organ of Corti, as shown in the former paper, general cochlear signs of otosclerosis ("*cochlear otosclerosis*" = "*c.o.*") ; on the other hand, osseous changes can be considered as situated near the high medium, or low scale of the cochlea, or affecting these areas by interference with the blood supply concerned. Then, they are able to cause "*basal cochlear otosclerosis*" = "*b.c.o.*" with high tone deafness, "*mid cochlear otosclerosis*" = "*m.c.o.*" with middle tone deafness, and "*apical cochlear otosclerosis*" = "*a.c.o.*" with low tone deafness, all of which are more circumscribed types against the unqualified "*c.o.*" just mentioned above.†

Such a classification, originating from pathological-anatomical considerations and partly backed by histological examinations already done (Crowe and others), in common with the main forms of progressive cochlear deafness, provides a basis for prognosis in the "order of *congenital types*" [*vide* Record XI, table I.]

Each sub-type of cochlear otosclerosis should show a characteristic curve of loss of air conduction.

The *apical cochlear otosclerosis* (*a.c.o.*), which should be associated with low scale deafness, is to some degree distinguished from classical otosclerosis when losses in bone conduction are present. Without such losses the case can be diagnosed only as suggestive of apical cochlear otosclerosis [Record VI B (i-vi)].

The *mid cochlear otosclerosis* (*m.c.o.*) shows lowering of the middle

\* The closely co-operating pathogenetic and nosoplastic factors cannot be disentangled. Genuinely, the fresh nervous irritation, following labyrinthine pressure in the vicious circle is not patho—"genetic", but its physiological parallelism with true pathogenetic conditions justifies the terminological inaccuracy

† The terms "basal", "mid", "apical" do not mean established histological lesions but rather clinical changes which, upon a *working hypothesis*, are referred to the respective parts of the organ of Corti. On the other hand, it is possible that the clinical types exist without strict reference to specific lesions in the organ of Corti

## Contributions to Functional Pathology—IV

part of the air curve around 1024, often extended to 512, rarely to 2048, the area of highest sensitivity and susceptibility, according to writer's discussions in previous contributions. The mid cochlear otosclerosis is not infrequent, but apparently not much different from unqualified cochlear otosclerosis. Only in relatively few cases is it associated with lowering of the bone conduction curve. However, even the separate analysis of these few cases of mid cochlear otosclerosis did not show a specific behaviour, compared with unqualified cochlear otosclerosis, on the "order of congenital types".

The unqualified *cochlear otosclerosis* is characterized either by individual air and bone conduction dips, usually at 1024 or 4096, and/or by negative Schwabach at least with one fork test, and/or by a fairly horizontal air conduction curve, with negative Rinne.

Intermediate between classical otosclerosis and (unqualified) cochlear otosclerosis seems to be the ordinary *non-classical otosclerosis* (*n c l o*). It is characterized by a more or less horizontal audiometric air curve, by a relatively high average Rinne (figures of all pitches available summed up and divided by the number of pitches), and by no obvious negative Schwabach. For special reasons [Appendix B, especially iii, iv] it resembles more cochlear otosclerosis than classical otosclerosis, and it is also in the "order of congenital types" more closely related to cochlear otosclerosis than to classical otosclerosis [Record XI, table I].

The *basal cochlear otosclerosis* is the most remarkable type of cochlear otosclerosis. It is characterized by negative Rinne over all, or nearly all, the scale, and especially by a greater decibel loss for air conduction, and mostly also for bone conduction, on the higher than on the lower scale [Record VII, Appendix C]. 36% out of 157 otosclerotic ears were of basal cochlear type. The importance of basal cochlear otosclerosis is the more evident as classical otosclerosis could be clinically identified only in 25% of our cases. *Basal cochlear otosclerosis* was present in several cases in which, according to the air conduction curve, *congenital cochlear deafness* was diagnosed by the first examiner.

The division of cases of *progressive cochlear deafness* is analogous. The great majority of 67%, amongst *in toto* 62 ears, is of basal cochlear deafness type—"b c d", 27% without definite localization cochlear deafness—"c d", 4 ears of 2 patients are of apical cochlear deafness type—"a c d" [Record VI A, re/"a c d"]

Amongst the otosclerosis cases a great majority shows, more or less, changes with *vestibular tests*. The percentage is high and noteworthy. Much lower is the percentage of vestibular signs in cases of progressive cochlear deafness [Record I]. If the genetic hypothesis comes near to the truth that progressive cochlear deafness is a descendent of "Primordial otosclerosis" (which seems to be so far only tacitly admitted, but not explained by regarding otosclerosis and progressive cochlear

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deafness as varieties of the same condition), then, the occurrence of quite a number of vestibular changes with progressive cochlear deafness is sensible, and even corroborative of the hypothesis of otosclerosis as the primordial form of progressive congenital deafness.

As a matter of fact, the important vestibular part of otosclerosis

DIAGRAM (1) of the different types of otosclerosis, with reference to audiometric curve and to bone conduction

TYPES	Audiom. curve ascen- dent from low to high.	Audiom. curve descen- dent from low to high.	Fairly hori- zont. curve, practically neither desc- end. nor ascend.	Dips or Gaps.	Schwabach (tun. fork).	Rinne (audiom.).
<i>cl.o.</i> : classical otosclerosis	low < HIGH				+ or ( $\pm$ o)	}
<i>n.cl.o.</i> : non- classical otosclerosis			fairly horizontal		$\pm$ o or (+)	
<i>c.o.</i> : (unquali- fied) cochlear otosclerosis			fairly and/or horizontal	dips c <sup>3</sup> c <sup>5</sup>	partly —	
<i>a.c.o.</i> : apical cochlear otosclerosis	low < HIGH				low tones — or ( $\pm$ o)	
<i>m.c.o.</i> : mid cochlear otosclerosis				mid scale gap	$\pm$ o or (—)	
<i>b.c.o.</i> : basal cochlear otosclerosis		LOW > high			low tones $\pm$ o or (+)	

must be graded with the mixed nosoplastic-pathogenetic factors in regard of vestibular influence on tympanic muscular activities. And, vestibular symptoms are, like tinnitus, purely nosoplastic by giving the whole picture of disease some uncomfortable varieties.

*Diagnosis.* Diagnosis of congenital deafness must be based on both audiometry and tuning fork tests. The fathers of otology founded the criteria of diagnosis on tuning fork tests. We should be cautious in

## Contributions to Functional Pathology—IV

correlating automatically tuning fork tests, such as Schwabach or Rinne, with the audiometric findings, as there cannot be ascertained any satisfactory identity of corresponding tuning fork and audiometer tests

In view of the different physical physiological conditions playing a part it is no wonder that occasionally e.g. differences even between tuning fork and audiometer Schwabach tests were encountered. The dilemma arising out of the differences between tuning fork and audiometric air curves is discussed in Appendix C III

*Auditory Diagnosis of Congenital deafness* depends on the division of otosclerosis, and progressive cochlear deafness in the types classical otosclerosis, non classical otosclerosis, cochlear otosclerosis, basal cochlear otosclerosis, cochlear deafness, basal cochlear deafness [*vide* diagram I]. The differential diagnosis depends on routine audiometry and tuning fork tests, and applies to fully established cases of deafness. The detection however of the *earliest* stage of deafness,—or even of the *potentiality* of deafness—in apparently *normal* members of *families* in which hereditary deafness has occurred, was impossible by using only the customary audiometric or tuning fork tests

A few sets of such family examination have been available in cases suggestive of heredity. Abnormalities, missing with the customary tests, were found however by using the steppage tests (decay period hearing) and by using the audiometric *provocative test* [Record VIII]

Preliminary results only on a small scale were so far available owing to the war conditions. For the latter reason it was impossible what seems to be a postulate of first order to perform in each suggestive family case not only detailed auditory but also vestibular tests

### Vestibular Diagnosis of Congenital Deafness

The vestibular tests, by using the "minimal caloric tests" can easily be done in any consulting room. Apart from exceptional cases, the response to cold water only is needed, and registered, with regard to intensity of nystagmus, every 30 seconds, as described in a former paper (*J Laryng and Otol*, 1943, LVIII, p 167). Simultaneously the factor of *directional nystagmus susceptibility* (directional Nystagmus Bereitschaft—Hallpike's directional preponderance) is *directly observed*, without any warm calorization [Record IX]

X-ray diagnosis proved to be useful in establishing an uncertain diagnosis

The otologist should use the incurable case as a fulcrum for *early* diagnosis of so far *latent deafness*. Systematic investigations and examinations of the patient's next of kin should become a routine procedure of diagnosis and not only a matter of occasional scientific research work

*Prognosis* Prognosis is based on individual and familial diagnosis

The prognosis, upon *familial* diagnosis, depends partly on a factor

which was stressed by Curtius in cases of hereditary nervous diseases, especially of sclerosis disseminata: the intensity of a degenerative nervous lesion is higher, when hereditary nervous abnormalities, even of different kind and on a minor scale, are present both on paternal and maternal side than with only one parental side affected. The power of manifestation—"penetrance"—of progressive congenital deafness differs according to the two alternatives.

The prognosis, upon *individual* diagnosis, depends amongst other conditions on the *average scale of deafness* of the individual types of progressive congenital deafness [demonstrated on Tables of Prognosis, Record XI]. The figures were taken out of a relatively large number of unselected cases of congenital deafness, and are based on the "audiometric index of deafness" and on the factor of "en bloc" capacity of hearing, both explained in former papers. The index of deafness, from which the consideration of en bloc capacity originated, provides not only a rough estimate of the individual case, but also an easy survey of a great number of individual cases the quantitative inter-relations of which cannot be calculated from audiograms. "En bloc" capacity and audiometric index of deafness are regarded as *Key-methods* which enable us to *compare* easily different stages and types of progressive congenital deafness on one common line, especially useful with regard to prognosis.

The diagram (2) reproduces a short survey of the figures of Record XI, table I, which are calculated upon the audiometric index of deafness. The diagram illustrates the "*Order of Congenital types*" of deafness, with special reference to prognosis. (3) shows with the different types the average magnitude of decibel loss, which ascends in a specific sequence.

DIAGRAM (2): The "Order of Congenital Types" with special reference to prognosis, increasing in severity from left to right.

Basal Cochlear Deafness.	(Unqualif.) Cochlear Deafness.	Classical Otosclerosis.	Non Classical Otosclerosis.	(Unqualif.) Cochlear Otosclerosis.	Basal Cochlear Otosclerosis.
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The Classical Otosclerosis is situated in the mid of the scale. By summing up the detailed figures of Record XI, except those of classical otosclerosis, there are

	> 60 db loss with	60 or < 60 db loss	Diagram (3): Rough estimate of average low and high rate of deafness with, more or less, cochlear otosclerosis and with progressive cochlear deafness respectively.
Otosclerosis more or less cochlear suspect	30%	70%	
Total of Progressive Cochlear Deafness	75%	25%	

## Contributions to Functional Pathology—IV

Prognosis concerns social, occupational, and familial outlook. These are a matter for practical organization on a broader line of social hygiene and eugenics. They can be outlined here, only with a few examples.

The choice of a child's profession might be much influenced by the existence of parental congenital deafness, if a boy, of practically normal hearing with routine hearing tests, is shown by the special tests as a probable, or at least possible, victim of progressive deafness, especially if he should be exposed to acoustic strain or hardships in his work.

Another question we are sometimes asked, when the first child has shown definite signs of deaf-mutism, is about the prognosis of hearing with a second child. The otologist's activity need not be restricted to the individual differential diagnosis between congenital, ante-natally, or post-natally acquired deafness, it should also be devoted to otological pedigree investigations by registration of family history, and by special examinations of next of kin cases [*vide* Record VIII].

Systematic research on social otology and otological hygiene with regard to prognosis of congenital deafness is a promising subject of practical otology.

*Therapy* The possibilities of *medical* therapy were discussed in Contribution No. I (*J. Laryng and Otol*, 1943, LVIII, II). Pessimism is justified with regard to the unalterable pathogenetic factors which steer relentlessly the course of pre-destination of the pathological genes. The chance of treatment is restricted to the variable nosoplastic factors.

The problem of improving the conditions of an individual, suffering from, or menaced by, progressive congenital deafness is the removal or avoidance of harmful environmental conditions, and/or in the writer's opinion, an attempt to cut, or at least to moderate the vicious circle maintained by spastic activities in the tympanic muscles which applies both to otosclerosis and to progressive cochlear deafness for the "nervous vicious circle" and alone to otosclerosis for the "periosteal vicious circle" [*vide* chapter on symptomatology (A)].

The otologist's help in cases of progressive congenital deafness is to face the impossibility of improving pathogenetic factors and to do all he can to avoid deteriorating nosoplastic influences. This prophylaxis applies to noxious factors of the working life, to careful avoidance of poisons (e.g., Nicotin) or drugs (e.g., Salicylate Aspirin). Furthermore, those well known cases, in which relatively slight colds or attacks of influenza are followed by an onset of hearing loss have taught us that the slightest residue of acute involvements with the middle or internal ear are worth treating by all means available. In cases of otitis interna following fever diseases an attempt should be made to improve the conditions by hypodermic protein injections the effect of which was not generally appreciated many years ago. The writer is well aware of the hopelessness of influencing directly a degenerative

nervous process following a fever disease. But the release of inflammatory, e.g., perineural, foci is quite different: the attempt to relieve a congenitally vulnerable nerve from noxious conditions of the vicinity. The writer's favourable experiences in inflammatory cases with protein injections encourage him to recommend this method, when properly applied, harmless, in a situation where no other medical therapy seems to be of avail.

The possibility of *surgical* therapy—method of fenestration—seems, in the writer's view, still to be problematic (*J. Laryng. and Otol.*, 1943, lviii, 11). However, another line of surgical therapy is suggested. It stands or falls with the adoption or denial of the principle of vicious circle caused by tympanic muscular hyperactivities, especially of "periosteal vicious circle" [*vide* Appendix D]. The tenotomy of tensor tympani, recommended during the early days of otology against "sclerosis" (Tröltzsch), for reasons now obsolete, could possibly be revived with the new perspective of cutting a part, in particular the "periosteal" part of the vicious circles, and, so, of moderating the harmful effect of the vicious circle. Cases of otosclerosis, and perhaps of progressive cochlear deafness, are envisaged, if selected upon *special indications*.

Another surgical procedure, following similar physiological lines, is under consideration.

### Conclusions

The preliminary notes of the paper, based on a fairly large material of progressive congenital deafness, need confirmation on an even larger scale. The preliminary conclusions are as follows:—

1. Otosclerosis is considered from the viewpoint of a primordial form of progressive congenital deafness. There seem to be three genetically distinguished forms of progressive congenital deafness the descendants of the primary "*Primordial Otosclerosis*": osseous otosclerosis, progressive cochlear deafness, and a compound of otosclerosis with progressive cochlear deafness.

The well known perivascular otosclerotic osseous changes are regarded as the cause of ischaemic lesions in the organ of Corti. This occurs on the one hand in the individual case; it becomes on the other hand of genetic importance with mutation. The resulting eventualities of genetic splitting up provide a genetic explanation of the mostly accepted view that otosclerosis and progressive cochlear deafness are varieties of the same condition.

2. The diagnostic significance of vestibular signs in progressive congenital deafness depends on the detection of changes in the "mute area" of the petrous bone, and, so, of conditions suggestive of latent congenital deafness. Vestibular tests are therefore regarded as an

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indispensable part of functional tests for progressive congenital deafness, especially for early diagnosis

3 Detailed vestibular and some new auditory tests indicated changes in progressive congenital deafness which are common to both otosclerosis and progressive cochlear deafness and make the whole clinical picture of progressive congenital deafness more intricate than it seemed to be when based only on the old routine auditory tests. Thus a certain confusion and diagnostic deadlock arose, in the field of clinical otology, analogous to a certain pathological-anatomical confusion due to advancing histological research on changes in progressive congenital deafness which, like the clinical findings, are also common to both otosclerosis and progressive cochlear deafness. However, the histological observations compared with our new clinical findings by combined detailed functional tests seem to corroborate each other—a clue to the clarification of the cloudy diagnostic situation is suggested upon laws of genetics [*vide* conclusion 1]

4 According to our clinical observations, the old classical form of predominantly ankylostapedial otosclerosis is less frequent than other forms of otosclerosis in which ankylostapedial signs are not predominant or not even detectable. The manifest form or some concealed forms of "basal cochlear otosclerosis" are of importance. These clinical conclusions are much in accordance with pathological anatomical findings of other authors.

5 The therapeutic approach to prophylaxis is the same for the diverse clinical forms of progressive congenital deafness, less for their genetical identity than for the reason that therapy and prophylaxis can so far be directed only against a secondary abnormality which is obviously common both to clinical otosclerosis and progressive cochlear deafness by combating abnormal activities in the tympanic muscles.

6 Progressive congenital deafness shows several types of behaviour of prognostic importance. These can be graded in an 'Order of congenital types' of deafness. The locus of the individual type of congenital deafness in this order seems to reveal some clinical qualities especially with a prognostic view of severity.

7 Progressive congenital deafness, the step child of therapy must become the interest of otological hygiene of defective hearing and the subject of otological practice and social welfare on a scientific basis.

### Appendix

A Albert Gray (*J Laryng and Otol*, 1934), found with otosclerosis a degenerative change of the cochlear nervous fibres, first in the medullary sheath, then in the neurilemma finally in the axis cylinder. This process is independent of the fixation of the stapes (or of the changes in the labyrinthine capsule, and is likely to precede both)



The words in brackets are not in accordance with the writer's view.

B. *Degree of manifestation of progressive cochlear deafness.*

The degree of clinical manifestation is on the average connected with, as said in the main text, but not always proportional to, a percentage of decibel loss. The minimum rate of decibel loss associated with defective hearing is definitely less with progressive cochlear deafness than with otosclerosis [*vide* diagram (3) and the figures re/40% db loss on tabular I, Record XI]. If only the basic morphological pathogenetic factors—the osseous and the cochlear nervous changes—were pertinent, then a loss of hearing should be expected proportional to the morphological changes of otosclerosis or progressive cochlear deafness respectively.

The argument that the difference in clinical manifestation is due to an earlier manifestation of congenital cochlear nervous than of middle ear changes does not correspond with our experiences on middle ear or internal ear changes in general. The opposite, rather, seems to be correct. And, as discussed in the paper, just internal ear conditions play an essential part in beginning otosclerosis, and not so much pure middle ear—ankylostapedial—factors.

The relatively early manifestation of progressive cochlear deafness can, however, be related to the higher variability in response of the tympanic muscles to the nervous stimuli with progressive cochlear deafness than to the less fluctuating conditions with otosclerosis when additionally the periosteal vicious circle is in operation. With otosclerosis, unless there is already osseous stapesfixation, the competition of two stimuli, the osso-periosteal and often the cochlear nervous stimulus, is apt not only to intensify but to stabilize to some degree the hypernormal muscular contraction. As discussed in a former paper (*J. Laryng. and Otol.*, lviii, 11; lix, 5), fluctuation of hearing capacity produces a greater consciousness of deafness than stabilized defective hearing on the same level of decibel loss: there is lack of "compensation" due to missing stabilization in cases of progressive cochlear deafness. And, so, the larger fluctuating muscular interference with progressive cochlear deafness is more easily manifest than in the relatively stabilized conditions with otosclerosis.

C. Discussion on *different types of congenital deafness* and interpretation of *audiometric air conduction curves*.

Amongst 67 ears of b.c.o., 9 more definitely than another 2 are suggestive of coincidence with classical (osseo-ankylosed stapedial) otosclerosis, some ears are dubious, but 46 out of 67 show no preponderance of clinical signs of ankylostapedial otosclerosis. 6% of c.o. cases are suggestive of a.c.o.; they cannot be definitely established owing to their low scale partly similar to classical otosclerosis. Only 18% could be diagnosed as purely classical otosclerosis; additional 7% cases of b.c.o. with coincident signs of classical otosclerosis, as mentioned just

## Contributions to Functional Pathology—IV

above, make the surprisingly low percentage of 25% of classical otosclerosis upon the analysis of combined audiometric and tuning fork tests. On histological p.m.s., M. Weber found 31% ossification round the stapes, against 69% otosclerotic changes in the petrous bone without stapes ankylosis.

The following objections could be raised:

C (i) It cannot be ascertained what percentage of M. Weber's p.m. cases of otosclerosis without osseous stapes ankylosis had defective hearing during their life time. In any case it is not logical to compare an anatomical with a physiological aspect of a problem, much the less advisable as, in our case, the parallelism between anatomical and physiological changes is the very point which is to be proved.

C (ii) It could be objected that more of my cases than identified by clinical diagnosis were cases of osseous ankylotic stapedia otosclerosis, that some of the c.o. type (without qualified distinction on low or high scale, *vide* diagram (1)), characterized by a fairly horizontal air conduction curve, are a combination of low scale classical otosclerosis and high scale basal cochlear otosclerosis (b.c.o.) with decreasing and increasing db loss towards the high scale respectively. This can be fairly disapproved: the curves of the few b.c.o. which showed also low scale deafness (as mentioned above, 9 definitely, 2 possibly amongst 67 b.c.o.) are quite different, they are marked by a 2 or 3 octaves interval of better hearing at the medium scale between the most defective low and high scale part of the curve. Checking of clinical with p.m. histological findings is needed.

The not infrequent fairly *straight horizontal curve*

C (iii) Langenbeck said (*Zeitschr. HNO Heilk.* 1936, report on International Congress) that the classical air conduction curve e.g., of middle ear lesion, obtained by the original auditory test with tuning forks looks different when the period figures of hearing sensation and their percentual rates of normal are calculated as corresponding figures of intensity with reference to audiometry. The tuning fork curve originally ascending from low to high, with middle-ear lesion, becomes a fairly straight horizontal curve of intensity figures. This would mean nothing other than to regard the audiometric horizontal air conduction curve as a correlate of the classical middle ear curve with tuning fork tests. Our audiometric air curves of stapes ankylosis (18%), ascending from low to high scale, would then be outstanding examples of middle-ear abnormality, of stapes ankylosis compared with the slight cases which show only an horizontal line with audiometry.

Further comment to the *horizontal curve*

C (iv) For the sake of simplification, the following implications of pitch specific conditions, with (unqualified) cochlear otosclerosis c.o., are not mentioned in the main text. It is not correct to say: the low

pitch-specific and the high-pitch-specific physiological negative Rinne, or rather their correlates of altered "bone conduction", prove that this is an obstacle to air conducted tones which is proportional only to the pitch-specific physiological magnitude of the muscular reflex; apart from these physiological conditions, the effect of the pitch-specific obstacle is also subject to the physical law that any middle-ear obstacle, independent of its morphological or physiological origin, causes more loss of hearing with the low than with the high scale tones. When, nevertheless, no definitely greater decibel loss is found with low than with high pitched tones, shown with the fairly horizontally straight air conduction curve, then the air conduction obstacle (referred to reflex hyperactivities in the tympanic muscles and estimated by figures of physiological negative Rinne) must be less with low pitched than with high pitched tones, and must originate from a relatively slighter cochlear irritation at the low than at the high scale. Consequently, the horizontally straight air conduction curve can be regarded as associated with minor cochlear lesion at low scale, major at high scale. These, however, are conditions of basal cochlear otosclerosis (b.c.o.). The horizontally straight air conduction curve hints, therefore, to less severe conditions of b.c.o. than the specific air conduction curve of b.c.o. descending from low to high scale.

Comparing even *non-classical otosclerosis* with cochlear otosclerosis rather than with classical otosclerosis is for its clinical behaviour, indicated by its position in the "Order of the congenital types" [Record XI, table I; and diagram (r)], no paradox; it is neither so far the considerable rate of physiological factors in the total negative Rinne, such as shown in Record V on physiological negative Rinne with otosclerosis as indication of an abnormal cochlear irritability.

As said in the chapter on diagnosis, it is quite misleading to refer mechanically diagnostic standards (shape of curves, Schwabach, Rinne), obtained by tuning fork tests, to principles of audiometry. Not only basic physical calculations bring about striking differences such as shown by Langenbeck, but also physiological differences dependent on whether a test of "efficiency" is done (e.g., first period in decay period hearing with tuning fork steppage test), or of "sensitivity" (last period or rather ultimate threshold with steppage tests): in the steppage tests a typical ascendent curve with first period can be associated with approximately horizontal curve obtained by ultimate threshold tests in one and the same case [for "efficiency", "sensitivity" *vide J. Laryng. and Otol.*, lix, 5 and lix, 9].

Conclusions reached on some 300 cases of progressive congenital deafness (200 combined detailed tests reported in the paper, and another 100 not tested on such a detailed scale) lead to the following interpretation of the air conduction curves with otosclerosis:

## Contributions to Functional Pathology—IV

1 The classical ascendent curve (in our material not more than 25%) with predominance of stapedial ankylosis

2 The horizontally fairly straight curve (in the relative majority of cases)

(a) clinically much of *n c l o* character (Schwabach "not" shortened, with lower tuning forks)

(b) clinically much of *c o* character (Schwabach shortened)

Both 2 (a) and (b) suggestive of *b c o* relationship

3 The descendent air conduction curve (in 36% of our cases) clinically manifest basal cochlear otosclerosis

C (v) According to (iv) it must be admitted, that not only cochlear otosclerosis but also non classical otosclerosis suggest basal cochlear features. The fairly horizontally straightened air conduction curve with non classical otosclerosis (*n c l o*) is nearly the same (yet sometimes a little ascending) as with (unqualified) cochlear otosclerosis (*c o*). This would mean that *n c l o* is, similar to *c o*, more or less related to the group of basal cochlear otosclerosis (*b c o*). Considering that the difference between *c o* and *n c l o* [*vide* diagram (1) in chapter symptomatology] is mostly the presence of some loss of bone conduction with *c o* and the absence of bone conduction loss with *n c l o*, it must be taken into account that this difference in Schwabach figures is based on relatively low scale tests such as only available with tuning forks, on the other hand, the minor or minimum scale of shortened bone conduction with high scale audiometry, which is easily regarded as not quite conclusive, might often be just as indicative of slight lesions in the high scale as the tuning fork Schwabach tests with low scale tones. By adopting, however, this viewpoint the *basal cochlear otosclerosis* becomes the *basic* form of *otosclerosis*, which is comprehensible in regard of the close vicinity of the "classical" peristapedial and the peribasal area. But this *pathological anatomical* unification cannot antagonize the differentiation in the *clinical* structure of progressive congenital deafness, which is illustrated in table I, Record XI and shows some marked prognostic differences between *c l o*, *n c l o*, *c o*, *b c o*, and especially a greater resemblance of *n c l o* to *c o* than to *c l o*.

D The *peristapedial periosteal factor*—the *periostat vicious circle*

A local factor, besides cochlear degenerative hyperirritability, plays an important part in the occurrence of hyperactivity in the tympanic muscles. If there are structural osseous changes or local metabolic *unrest* at the oval window, near the surface but still not reaching the surface and still far from producing osseous ankylosis, it is quite plausible to expect a hyperirritability of the tympanic muscles closely situated to an area of structural and metabolic unrest.

According to Gebhardt (quoted by Bruhl), the osseous changes with stapes ankylosis are likely to be intensified by an effect of push and pull

force. The cartilage-covered plate of the stapes is fixed at the cartilaginous border of the oval window by tendon-like fascicles of connective tissue. Just at the anterior circumference of the stapes lies the musculus tensor tympani the tendon of which passes along the cochleariform process to the malleus (cited by Brühl, *Beitr. Anat. Physiol. Ohr. etc.*, 1910). The contractions of the tensor tympani reflex cause a permanent unrest in the periost and in the bone between tendon and annular ligament of the stapes (Brühl). The writer's conclusion is: On the one hand, the periosteal unrest must be of greater magnitude when structural osseous changes occur or are about to occur such as with otosclerosis. On the other hand, mutual influence between osseous or periosteal unrest and muscular irritation is understandable. So, reversely, the normal irritation and irritability of the musculus tensor tympani becomes gradually a state of growing hyperirritability. A *local vicious circle* arises associated with activities of tympanic muscles: *local periosteal vicious circle* [vide reflex arch nervous vicious circle, chapter on symptomatology, section: mixed pathogenetic-nosoplastic factors].

Cochlear nervous (reflex arch) and tympanic muscular (periosteal) hyperirritability, both attributed to otosclerotic osseous changes in their respective vicinity, are probably able to produce signs of stapesankylosis which are only the effect of a muscular spastic rigidity: "spasmo-ankylosis stapedial otosclerosis".

## Records and Comments

### RECORD I

*Vestibular signs and symptoms with Progressive Congenital Deafness.*

62 cases of otosclerosis, 19 of progressive cochlear deafness were systematically subjected to the writer's detailed vestibular tests, since beginning of January, 1943 up to end of February, 1944. *Most noteworthy:*

H. Margaret, 32. Complaints of some unsteadiness, heavy noises in the head; throbbing for hours after riding in bus, unlocalized "headache"

#### VESTIBULAR TESTS

- (1) January, 1943: extreme *hyper* excitability 20° and 25° 5 c.c.; gross Nyst., very sick.
- (2) March, 1943: definite *sub* normal excitability 20°, 25° 5 c.c., also 15° 10 c.c. Question of *central lesion*?
- (3) May, 1943: *sub* normal with 17° 5 c.c., 10 c.c., or 28° 10 c.c.
- (4) August, 1943: less subnormal.

#### AUDITORY TESTS

- (1) January, 1943: "Auditory index" Right 12, Left 10; (8192) right +4, left +10. Provocative Rinne negative (normal).
- (2) March, 1943: Index Right 18, Left 17.
- (3) May, 1943: Index Right 17, Left 21.
- (4) August, 1943: Index Right 30, Left 24; provocative Rinne right +10, left -1 (right abnormal).

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Comment to findings of August, 1943

This is a significant case of direct observation of directional nystagmus susceptibility (to right) Suspicion of insidious central lesion (*vide* March) was dropped Directional Nystagmus susceptibility, during last months frequently noted with otosclerosis, became suggestive of otosclerosis also in this case

(5) February, 1944. no vestibular tests

## AUDITORY TESTS

Aud om Index: Right  $14\frac{1}{2}$ , Left  $19\frac{1}{2}$ . Provocative Rinne: right  $+6\frac{1}{2}$ , left  $-3$

## MID/END NYSTAGMUS TEST

21° 10 c c

Mid position

Right ear

Left ear

20/25° first response

60°

no

90°

response

120° ±

Right ear

End position

Left ear

right ←

Nyst

→ left

right ←

Nyst

→ left

0	45/50°	(+)	includ	} ++ 20°	
> (+)	60°	> (+)	Nyst		
> (+)	90°	((+))?	3rd degree		
(+)	120°	> (+)	+		60°
(+)	150°	0	+/(+)	90°	0
(+)	180°	0	Prov (+)	120°	0
((+))	240°	0	Prov ((+))	150°	0

## GENERAL CONCLUSION

In spite of negligible, and fluctuating loss of hearing, seen in the varying audiometric indices (1 to 5), the preliminary suggestion of August, 1943 was maintained in view of a further series of cases of otosclerosis characterized by vestibular signs X-ray examination confirmed changes in the petrous bone related to otosclerosis

Summary of 81 cases.

Otosclerosis: 62 cases (124 ears). More or less vague complaints 7, definite giddiness 10 cases.

### Vestibular signs

(a) Directional Nystagmus susceptibility direct observation 7 calculation (upon cold/rotat or cold/warm tests) 8 cases

(b) Subnormal Excitability (20° 10 c c. no response, stronger stimuli up to 16° 10 c c no or poor response) 38 ears Rotatory abnormal were 6 cases 4 of them up to 5 rotat practically no response, 2 even up to 10 rotat 5 out of the 6 cases were also definitely caloric subnormals

(c) Spontaneous Nystagmus 3 cases

(d) Mid/End Nystagmus Mid=End (or Mid>End) 32, End>Mid 63 ears

Progressive Cochlear Deafness: 19 cases (38 ears). Vague, or e.g. hypertonic, complaints 5 Definite giddiness attacks, but, for obvious objective findings to be discussed in a later paper, independent of the progressive internal ear lesion: 2 cases, P. Harry, 58, B. Mary, 71.

*Vestibular signs*(a) *Directional Nystagmus susceptibility*: direct observation 1, calculation 5 cases.(b) *Subnormal Excitability*: caloric 7 ears; rotatory 2 cases (one of the latter also caloric subnormal).(c) *Spontaneous Nystagmus*: no case.(d) *Mid/End Nystagmus*: Mid=End 29 ears; End>Mid 2 ears. However, the latter are related to case B. Agnes, 73, with otosclerotic strain [vide form 2c of Primordial Otosclerosis, in chapter on Genetics, and Record III, 2, iii] and to case D. Arthur, 70, [Record III, 2, ii] respectively: D. Arthur was somewhat arbitrarily grouped with progressive cochlear deafness on his evidence of positive Rinne and negative Schwabach F with fork e<sup>1</sup> (and to the beginning of deafness only when he was 55), in spite of definite negative Rinne with fork e.

TABLE I

Tables on Vestibular signs with Progressive Congenital Deafness.

	62 cases=124 ears Otosclerosis			19 cases=38 ears Prog. Coch. Deafness			On the whole Otosclerosis + Cochl. Deafness number of ab- normals.
	Total number of cases or ears.	Number of Abnormals.	%	Total number of cases or ears.	Number of Abnormals.	%	
(a) Directional Nystagmus susceptibility	62	14	22.5	19	6	31.5	14 + 6=20
(b) Subnormal Excitability	124	40	32.5	38	5	13.5	40 + 5=45
(c) Spontaneous Nystagmus	62	4	6.5	19	0	0	4 + 0=4
(d) End=Mid Nystagmus	124	30	24	38	29	76.5	30 + 29=59
(e) End>Mid Nystagmus	124	57	46	38	2	5	57 + 2=59
(f) Definitely Normal	124	8	6.5	38	18	47.5	8 + 18=26

*Résumé.* The rate of 96.5% of otosclerosis compared with 3.5% of progressive cochlear deafness [table IIe] is striking, much the more by considering that the negligible rate of 3.5% is related to B. Agnes and D. Arthur who in the summary above on Progressive Cochlear Deafness were discussed as suggestive of otosclerosis [sub (d)].

The rate of 9 : 1 [table IIb] is also noteworthy.

The rate of 2.5 : 1 [table IIa] on unqualified directional nystagmus susceptibility is not very significant. The rate is quite different, if,

# Contributions to Functional Pathology—IV

according to the footnote of IIa, only cases with the writer's direct observation of directional nystagmus susceptibility are taken into account, such as illustrated with case H. Margaret, above. (Results of calculation of directional nystagmus susceptibility, both upon Hallpike's standardization of Vogel's cold/warm test and upon the writer's cold/rotator test should be taken with due reserve, except in gross cases

TABLE II

On the whole	Otoscler. + cochl deafness	hereof otoscler	%	Otoscler + cochl deafness	hereof cochl deafness	%	Diagnostic relationship Otosclerosis progressive congenital deafness
(a) Directional Nystagmus susceptibility	20	14=	70	20	6=	30	ca 2 5 1 (or 7 1*)
(b) Subnormal excitability	45	40=	89	45	5=	11	ca 9 1
(c) Spontan. Nystagmus	4	4=	100	4	0=	0	Otosclerosis only (small statist number !)
(d) End=Mid Nystagmus	59	30=	51	59	29=	49	ca equal
(e) End>Mid Nystagmus	59	57=	96.5	59	2=	3.5	ca 24 1
(f) Definitely Normal	26	8=	>31	26	18=	<69	ca 1 2

\* Upon qualified directional nystagmus susceptibility, (vide résumé)

which are not often concerned with progressive congenital deafness) Among only 8 cases available of direct observation 7 are otosclerosis, 1 progressive cochlear deafness. However, this is, again, the case D Arthur, who was repeatedly mentioned as somewhat arbitrarily grouped with cochlear deafness. *Directly observed* directional nystagmus susceptibility is obviously a rarity with progressive cochlear deafness

Table II f illustrates the pathological-anatomical findings and genetically based probability of otosclerotic changes with progressive cochlear deafness, by referring vestibular abnormalities in cases of cochlear deafness to otosclerotic changes, of course if other causes of vestibular abnormality can reasonably be excluded.



*Conclusion.*

On the one hand, vestibular tests demonstrate the interwoven features of otosclerosis and progressive cochlear deafness; on the other hand, vestibular tests seem to be helpful in the diagnostic differentiation between the two forms of congenital deafness, by the *detection* of so far latent changes in "mute areas" of the *petrous bone*.

RECORD II

Examples of *Progressive Congenital Deafness* with *Mother and Child*.

9 families with progressive congenital deafness show identical type of deafness.

Non identical type was found with 2 families.

(1). K. Joice, 16, classical otosclerosis. Her mother, 56, slight cochlear deafness; even if referred to age, a premature case of presbycusis and a relatively much advanced one.

Audiometry: C to c<sup>4</sup> practically normal; c<sup>5</sup>, c<sup>6</sup>, right 55, 67, left 46, 59 decibel loss.

(2). H—y family.

(a) Mother, 46, *otosclerosis*; *audiom. index* right 397/..6=66, left 378/..7=54; *Forks*: (e) Rinne both —, Schwabach right +, left normal; (c<sup>4</sup>) Rinne both —, Schwabach right normal, left + +.

(b) daughter Is., 12, *progressive cochlear deafness*; *audiom. index* right 392/8=49, left 396/8=49½; *Forks*: (e) Rinne both +, Schwabach right —, left ((—)); (a<sup>1</sup>) Rinne both +, Schwabach both —.

(c) daughter M., 16, *progressive cochlear deafness*; *audiom. index* right 344/8=43, left 342/8=43; *Forks*: (e) Rinne right (+), left +, Schwabach both —; (a<sup>1</sup>) Rinne both +, Schwabach both —.

(d) son David, 20, *progressive cochlear deafness*; *audiom. index* right 462/8=58, left 437/8=54½; no bone conduction (audiometry) both with 64, 128, 2048, 8192, and left with 256.

(e) son M., 9; according to tests at several dates over a period of one year: suggestive of beginning *otosclerosis* (fluctuating slight decibel loss, uncertain provocative test, suggestive vestibular responses). The case, which was tested for scientific reasons, is of course not registered with the survey on our otosclerosis cases mentioned in other Records of this paper.

(f) daughter G., 14, *normal*; with *Forks* even hypernormal; *audiom. index* right 120/8=15, left 84/8=10½, quite excellent hearing in the conditions of our sound-proof room.

(g) son Denis, 22, not available. Is *normal* (mother's report).

RECORD III

*Coincidence of Otosclerosis and Progressive Cochlear Deafness* in the same case.

Type (1): so-called unilateral otosclerosis. Small findings with the "normal" ear indicate, according to the writer's earlier observations over a period of many years, that fully established unilateral otosclerosis is often associated with slight but unmistakable signs of cochlear deafness in the "normal" ear [*Practica Otologyng.*, I, 3-4].

## Contributions to Functional Pathology—IV

This fits in with our view on primary cochlear deafness with otosclerosis taken in the chapters on anatomy and on genetics. Such cases are not representatives of a clinically *established* Primordial Type of Otosclerosis, such as illustrated below with cases of type (2); but type (1) is the clue to type (2).

### CASES OF TYPE (1):

(i). W. Hilda, 31, right ear deaf one year gradually: cochlear otosclerosis.

Right audiom index Air C 64 db, average Rinne -43.

Left audiom index Air C 27 db, average Rinne -1

Tuning fork (e) Rinne right -, left -, Schwabach right normal, left slightly shortened

(ii). S. Annie, 53, right deaf for a while; cochlear otosclerosis

Right audiom index Air C  $429/6 = 71\frac{1}{2}$  average Rinne -50.

Left audiom index Air C:  $250/8 = 31$ , average Rinne -5

Tuning forks (e) Rinne right -, left +, Schwabach right normal left slightly shortened (a<sup>r</sup>) Rinne right -, left +, Schwabach right normal (?), left definitely shortened

(iii). O'Co, Joseph, 41, right ear 3-4 years deaf, throbbing non-cochlear otosclerosis.

Right audiom index  $356/5.5 = 71$ , average Rinne -53.

Left audiom index  $157/8 = 19\frac{1}{2}$ , average Rinne -6

Tuning forks (e) Rinne right -, left ?, Schwabach right normal (?) left normal (?) (a<sup>r</sup>) Rinne right -, left +, Schwabach right normal (?), left definitely shortened

(iv). W. Mary, 45, tinnitus and deafness left several years, right all right: n.c.o.

Right audiom index  $212/8 = 26\frac{1}{2}$  db, average Rinne -5.

Left audiom index  $420/7 = 60$  db, average Rinne -46

(db loss Right 64 to 8192 28 24 24 24 22 10 32 48)

Tuning forks (e) Rinne right +, left -, Schwabach right - left normal (?) (a<sup>r</sup>) Rinne right +, left -, Schwabach right normal (?), left +

(v). L. Peter, 24, right deaf several months, left "all right" basal cochlear otosclerosis.

Air C { Rt 41 45 44 52/63 87 78 62 (db loss 64 to 8192), aud ind = 59, average Rt -51,  
Lt 24 22 17 25/35 48 55 38 (db loss 64 to 8192), aud ind = 33 average Lt -1

Tuning fork tests less characteristic in this case; however audiometry demonstrates, according to the marked differences in Rinne's test. Right b.c.o. (basal cochlear otosclerosis), Left b.c.d (basal cochlear deafness).

The "good" ear in another 5 cases of "unilateral otosclerosis" shows already definite—middle ear type—otosclerosis. In two cases, the good ear was objectively normal.

Subjectively unilateral deafness was encountered in 12 out of 157

well established cases of otosclerosis, i.e. in 8%, objectively unilateral deafness in only 2 cases, i.e. in  $>1.3\%$ .

## CASES OF TYPE (2).

### Established *Primordial* Type of *Otosclerosis*.

Case (v) of type (1) could equally well be ranged with type (2), for the magnitude of the objective changes, although no changes at all were noticed by the patient, and added as 5th case to the following 4 cases.

(i). R. Zachariah, 52; right gradually deaf 10 years, left "all right".

Frequencies: 64 1024 4096 8192 average  
 Air C { Right 59 66 64 65/68 60 95 x; audiom. index  $477/7 = 68$ ; Rinne -33  
           { Left 41 38 33 33/33 30 78 +; audiom. index  $286/7 = 41$ ; Rinne -6  
 Tuning Forks: (e) Rinne right -, left +, Schwabach right normal, left (-);  
                   a<sup>1</sup> Rinne right -, left +, Schwabach right normal, left (-).

*Diagnosis*: Right b.c.o. (basal cochlear otosclerosis), Left bcd (basal cochlear deafness).

(ii). D. Arthur, 70, deaf gradually 15 years.

*Diagnosis* of the surgeon of the out-patients' clinic: Otosclerosis. The case was referred for scientific research, which made the diagnosis not clearer but rather ambiguous. As a matter of fact, the very ambiguity is characteristic in such cases. I preferred to make The diagnosis of progressive cochlear deafness, partly regarding the late appearance of deafness (55), partly the very bad Bone Conduction with audiometry. On the other hand, the vestibular signs of the case came out to be in progress of research work, much in favour of unilateral—vestibular—otosclerosis.

Air C { Right 58 65 70 78/81 82 86 +; no bone Cond. at all.  
           { Left 57 63 69 78/80 74 80 x; bone cond. only with 128 and 256.  
 Tuning Forks: (e) Rinne right -, left -, Schwabach right -, left -; f  
                   (e<sup>1</sup>) Rinne right +, left +, Schwabach right -, left -.

*Diagnosis*: (Primordial) Duality of Otosclerosis and Cochlear Deafness.

(iii). B. Agnes, 73, gradually deaf ca 10 years.

average Rinne  
with c to c<sup>2</sup>

Air C { Right x 75 80 93/110 93 x x; audiom. index  $451/5.5 = 90$ ; Ri -49  
           { Left 44 48 52 54/73 72 75 x; audiom. index  $418/7 = 60$ ; Ri -16  
 Tuning Forks: (e) Rinne right -, left +, Schwabach right -, left -;  
                   (e<sup>1</sup>) Rinne right -, left +, Schwabach right -, left -.

*Diagnosis*: The relatively small negative Rinne, left (audiometry), is suggestive of a "physiological negative Rinne" indicating progressive cochlear deafness left. The marked difference with Tuning Forks between right and left tells the same story. (X-ray examination is missing.) Summarized: Clinical Otosclerosis right, progressive cochlear deafness left.

(iv). T. Jack, 41; right deafness for years, worse last 2-3 months; left ear not good a short while.

Air C { Right 56 58 55 77/89 70 74 x; audiom. ind.  $479/7 = 68\frac{1}{2}$ ; Ri = -40  
           { Left 45 34 30 37/53 43 63 61; audiom. ind.  $366/8 = 48$ ; Ri = -18  
 Tuning Fork: (e) Rinne right -, left +, Schwabach both ((-)).

*Diagnosis*: Right b.c.o. (basal cochlear otosclerosis), left highly suggestive of b.c.d. (basal cochlear deafness).

*Conclusion*. Clear distinction between the two types of congenital

# Contributions to Functional Pathology—IV

deafness in the right and left ear respectively can hardly be expected. On the one hand, the relative unreliability of clinical signs of diagnosis must be duly taken into account. On the other hand, our discussions on anatomy and genetics, in the respective chapters, led to the plausibility that no strict separation but rather transient clinical forms of both types of congenital deafness should be encountered. The qualified discrimination of the 4 cases (or 5, by inclusion of case v, type 1) of type 2 is sensible and justified.

## RECORD IV

### *Genetic Relationship between Otosclerosis and Vestibular Vertigo*

The following case might seem to be a rarity as the only one of this kind really recorded. However the circumstances are unfavourable for checking reports on deafness of relatives. It is not exceptional that, with a case of vestibular vertigo, without otitis, answers, to inquiries on defective hearing of next of kin, are in the affirmative. Therefore I do not regard the following case as quite unusual, but only as unusually representative.

H. Sidney, 24, typical attacks of vertigo with sick feeling, and temporary slight circumscribed loss of hearing.

decibel loss frequencies	{	Right	29	31	24	25	35	21	29	26	=27½
		Left	28	31	25	37	50	31	18	32	=31½
			64		256		1024			8192	audiom index

Three months later

decibel loss	{	Right	21	22	12	17	24	17	23	13	=18½
		Left	17	15	13	13	17	13	13	15	=14½

On inquiry of any deafness of next of kin: mother deaf since the patient's birth.

Mother's case

H. Sybill, 57, more than 30 years ago attacks of falling, no less of hearing, then. Since pregnancy with son above, 24 years ago, increasing deafness. Right ear nil, Left ear shouting. Noises both ears.

*Auditory tests*

Right	{ Air C	x	x	x	x	x	x	x	x
	{ Bone C	24	34	39	x	x	x	x	x
Frequencies		64		256		1024			8192
Left	{ Air C	60	72	87	95	95	100	x	x
	{ Bone C	24	38	39	?	x	x	x	x
Frequencies		64		256		1024		2048	
X rays	++	Preliminary Diagnosis				Basal Cochlear Otosclerosis (b c o)			

*Vestibular tests*

18°5 c c both ears no response 18°10 c c right no response left very poor response  
Labyrinth chair 2 rotatory both direct poor response 5 and 10 rotatory no response  
not the slightest giddiness

*Definite Diagnosis* Panlabyrinthine Otosclerosis (Basal Cochlear + Vestibular Otosclerosis)

## RECORD V

No	Name	Age	Diagnosis	Index of Deafness Right Left	Provocative Rinne Right Left	Routine Physiol Rinne Right Left	
(1)	J Alfred,	64	Ménière especially left	40 61	-4 +1	-17 -35	
(2)	M Robert,	48	Progressive cochl deafness	44 38	+5 -4	-16½ -9	
(3)	St Stanley,	29	Ménière left	18 21½	-6 +3	-3 -5	left ear noises, 1024-8192 { right 19 10 13 10 Audium left 25 21 16 53 } AHC
(4)	B Lothar,	18	Ménière (Migraine)	23 14	+1 -10	-9 +6	right ear buzz 64 and during gdd 1024-8192 { right 36 21 10 15 38 attacks, left 20 19 6 12 9
(5)	D Ross,	25	Ménière	37 40	+2 +6	-14 -17	left noises, left hearing not alright
(6)	H Sidney,	22	Ménière (22 9 43) 8 10 43	27 31	-2 +12	-4 -15	64 and 1024-8192 { right 29 35 21 20 26 left 28 50 31 18 32
(6a)	H Sidney,	22	Ménière (22 9 43) 14 1 44	18 14	+2 -11	-5 ±0	no more complaints
(7)	P Mahel,	46	Ménière	34 69	-1 +10	-12 -35	Transfer of sound from right to left ear was excluded by the Bartny Box tests
(8)	R Alfred,	46	Ménière	77 51	+10 -3	-55 -30	some Glosclerotic component?
(9)	H Leonard,	48	Ménière	33 39	-8 -7	±0 -8	? Difference with Provocative Rinne unconvulsive right/left
(10)	A Florence,	37	Ménière	32 51	-13 +13	-7 -22	
(11)	Sh Lilly,	40	Progressive cochl deafness	35 43	+1 +2	-5 -12	? Difference with Provocative Rinne unconvulsive right/left
(12)	M Edith	46	incip cochl deafness	42 31	-7 -17	-20 -9	
(13)	B May,	47	Nervitis VIIIth especially left (a) 6 4 43 (b) 2 7 43 (c) 14 7 43	28 55 37 57 26 57	-20 +1 -3 -4 -16 +1½	-1 -26 -16 -31 -14 -26	- ? Difference with Provocative Rinne unconvulsive right/left
(14)	A John,	49	Nicotin VIIIth nerve	18 18	+1 -29	-6 -3	
(15)	L Joseph,	69	Progressive cochl deafness	27 41	-13 +4	-1½ -26	
(16)	B Mary	71	Progressive cochl deafness	44 43	-13 -1	-7 -13	
(17)	P Gwendoline	22	Ménière (VIIIth crisis) (a) 23 1 43 (b) 16 3 43 (c) 23 2 44	12 12 22 17 13 17	-3 +4 +9 +9 +5 -5	+2 -4 -7 -3½ -11 +5	? — no difference with Provocative Rinne right/left
(18)	G Ernest	45	Ménière	26 26	-14 -9	-10 -6	paradoxical i e non reciprocal (provocative/routine Rinne)
(19)	D Brian,	21	Progressive cochl deafness rt	24 22	-14 -9	-10 -6	

# Contributions to Functional Pathology—IV

## Comments

(a) 4 out of 25 tests (No 9, 11, 13b, 17b) indicate an equal or almost equal Provocative Rinne right/left, they are unconvulsive. One case (18) is paradoxical 20 show typical "reciprocal behaviour", some of them on a minor scale, several definitely such as (1), (6), (7), (8), (10), (13) and others "Reciprocity" means the side of major negativity with physiological Rinne is mostly, i.e. in typical cases, the side of minor negativity with provocative Rinne, and *vice versa* (Negative Rinne reaching and passing the zero level becomes, reversely, positive)

It is hardly possible to explain the provocative Rinne except by physiological changes in the tympanic muscles (*J Laryng and Otol*, 1944, lxx, 9). The physiological interdependence (reciprocity) between Provocative Rinne and Routine Rinne such as demonstrated on the table, points to the extreme probability of the *negative physiological Rinne* also originating in activities of the *tympanic muscles*

(b) The interrelation between physiological and provocative, negative Rinne cannot be expected to be so typical with cases of otosclerosis as with those of non otosclerotic cochlear deafness. The quantitatively fairly correspondent reciprocity was calculated with cases of *cochlear deafness* in the following way. The difference in decibel loss between right and left of all of 19 available cases was summed up for the Routine Rinne and for the Provocative Rinne, amounting to 272 and 279 db respectively. The average rate of difference in an individual case is  $\frac{1}{19} = \text{ca } \frac{1}{3}$ . The corresponding figures with 36 cases of *otosclerosis* as to Routine Rinne and Provocative Rinne are 395 and 263 db respectively. The corresponding average rate of difference in an individual case is  $\frac{395-263}{36} = 3\frac{2}{3}$  decibels

This means "against an approximate quantitatively equal, though reciprocal, change with both Rinne tests (figure  $\frac{1}{3}$  is fairly negligible) with cases of cochlear deafness, there is an average difference of  $3\frac{2}{3}$  db with cases of otosclerosis. The morphological peristapedial changes of otosclerosis are obviously inhibiting to some degree the physiological changes involved. To exclude as far as possible this "morphological error", the cases of otosclerosis were graded (a) unselected, (b) by exclusion of cases with difference of provocative Rinne between right and left ear, of less than 5 db, i.e. only 1 db more than the possible "error" of  $3\frac{2}{3}$  db

## CASES OF OTOSCLEROSIS

with provocative Rinne on unselected cases (50)		with provocative Rinne on a scale of right/left difference of 5 or <5. decibels (28 cases)	
typical	paradoxical	typical	paradoxical
36 cases=72%	14 cases=28%	23 cases 82%	5 cases=18%
(Out of 22 cases of provocative Rinne on a scale of right/left difference of less than 5 db only 13=59% were typical and 9=41% paradoxical)			

## F. Kobrak

On the whole, these records on otosclerosis can be taken, with due criticism, as a certain confirmation of the figures of purely physiological negative Rinne with cochlear deafness. The records on otosclerosis are at least highly suggestive, that—(muscular)—conditions of the *physiological negative Rinne*, increasing the magnitude of the morphological negative Rinne, have to be included in our diagnostic calculation in those cases or stages of *otosclerosis* where *stapedial fixation* is not yet fully developed.

### RECORD VI

APICAL COCHLEAR CASES suggested by defects in *low scale* bone conduction.

A. "a.c.d." (apical progressive cochlear deafness).

(i) M. Colette, 16.

Audiometry

Right	{ Air C.	60	74	76	75/70	51	47	×
	{ Bone C.	×	×	?	?/53	53	42	×
	{ Frequencies	64		256	1024		4096	
Left	{ Air C.	60	72	62	65/66	50	47	×
	{ Bone C.	×	×	×	?/54	42	38	×
	{ Frequencies	64		256	1024		4096	

Her father, 48 typical b.c.d. (basal cochlear deafness).

(ii) K. Mrs., 50.

Audiometry

Right	{ Air C.	47	52	53	61/67	59	53	55
	{ Bone C.	×	×	×	×/63	53	54	×
Left	{ Air C.	47	52	53	59/63	59	61	46
	{ Bone C.	×	×	×	×/63	×	55	45

Case (i) specific "a.c.d." with air and bone conduction; case (ii) only with bone conduction.

B. "a.c.o." (apical cochlear otosclerosis).

(i) G. Ena, 41; only right ear suggestive of a.c.o.

Right	{ Air C.	×	×	77	87/86	74	68	×
	{ Bone C.	×	32	×	43/61	38	46	×

(ii) O. Vera, 26.

Right	{ Air C.	×	73	85	85/97	77	66	60
	{ Bone C.	×	×	31	31/51	40	30	30
Left	{ Air C.	×	×	(73)	97/107	94	90	(68)
	{ Bone C.	×	×	×	43/61	50	40	(43)

(iii) B. Nelly, 56; only left ear suggestive of a.c.o.

Left	{ Air C.	×	75	74	73/74	53	41	×
	{ Bone C.	×	×	40	41/45	38	33	×

# Contributions to Functional Pathology—IV

(iv) D. Mary, 35; February, 1944.

Right	{ Air C	x	x	79	74/84	61	57	63
	{ Bone C	x	x	x	x/x	54	31	x
Left	{ Air C	x	x	82	81/92	72	51	60
	{ Bone C	x	x	x	x/x	43	37	x
The same patient more than 2 years ago c/o (classical otosclerosis) December, 1941								
Right	{ Air C	x	73	76	83/79	57	52	67
	{ Bone C	14	11	+2	0/43	16	17	33
Left	{ Air C	x	x	77	71/81	48	48	33
	{ Bone C	21	27	17	25/47	18	21	24

The audiometric index of deafness was

	Right Air Conduction	Left Air Conduction
1941	$487/7 = 69\frac{1}{2}$ db	$358/6 = 59\frac{1}{2}$ db
1944	$418/6 = 69\frac{1}{2}$	$438/6 = 73$

The deterioration with Bone Conduction is catastrophic in both ears, that of Air Conduction remarkable left, slight in the right ear

(v) M. Rosa, 34, throbbing "dynamo" noises

Right	{ Air C	x	x	x	97/86	78	83	x
	{ Bone C	x	x	x	48/58	52	43	x
Left	{ Air C	x	75	84	78/72	56	57	x
	{ Bone C	x	35	35	32/51	36	48	x

Tuning Forks Schwabach (e) and (a<sup>1</sup>) both ears definitely shortened Right suggestive of a c o, Left classical otosclerosis

X-rays On each side considerable zone of dense bone surrounding the superior semicircular canals

Caloric tests Both ears subnormal excitability (no response with 17° 10 c c) There was, only Right (side of a c o), End > Mid nystagmus whereas Left normally End = Mid

(vi) M. Doris, 33

Right	{ Air C	60	72	69	65/69	58	40	40
	{ Bone C	x	x	25	18/40	34	27	43
Left	{ Air C	60	63	62	62/56	54	51	54
	{ Bone C	x	x	27	17/32	31	24	39

Tuning Forks (e) Rinne both —, Schwabach right —, left —

(a<sup>1</sup>) Rinne right —, left ?, Schwabach both normal

Diagnosis Classical Otosclerosis?, but for Bone Conduction missing (64) and (128) audiometry Bone Conduction extremely shortened (e), Tuning Fork right ear more than left, especially Right ear highly suggestive of a c o

Conclusion. The interpretation as apical cochlear otosclerosis must be, preliminarily, a purely clinical one saying that clinical signs are pointing to a c o Confirmation by histological examination is needed Eventual ossification on both windows has to be taken into consideration, as an alternative

## RECORD VII

Examples of BASAL COCHLEAR OTOSCLEROSIS b c o

(a) Diagnosis "Otosclerosis" confirmed by X-rays

(i) W Ethel, 35, the Key-case, which was suggestive of "cochlear otosclerosis". History 3 years left deaf after bad cold Buzzing noises Right ear good No family history.



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## Audiometry

Left	Air C	37	42	24	23/31	63	59	65
	Bone C	21	26	19	12/27	18	27	27
	Rinne	-16	-16	-5	-11/-4	-45	-32	-38
Right	Air C	32	28	22	16/12	17	11	11
	Bone C	x	31	22	21/31	23	18	28
	Rinne		+3	±0	+5/+19	+6	+7	+17

## Tuning Forks steppeage tests

Right missing, Left with (250), (1000), (4000) d v { 49, 33, 27% First step periods  
100, 51, 40% Ultimate Thresh-  
holds

Summary Left definite decrease from low to high scale, with both audiometry and tuning forks

The diagnosis, based on the tests, was *cochlear deafness*. Yet, we should have been warned by the individual relatively high negative Rinne -45 at (2048), and by the definitely negative Rinne (4096) and (8192) of a magnitude exceeding, or at least at the limit of, physiological negative Rinne. Mr Watkyn-Thomas, who referred the case for audiometry noted some otosclerotic signs of otosclerosis and sent her also for X-rays. Left pericanal cloudy zone, suggestive of *Otosclerosis*.

The X-ray diagnosis was right, in view of numerous analogous cases encountered later on. The preliminary conclusion was some features of hearing tests, generally due to "cochlear deafness", are often found in a well characterized group of otosclerosis high scale deafness associated with relatively high negative Rinne, even with Schwabach + (tuning forks) on low scale. This is b c o

(ii) V. Charles, 56; Right ear gradually worse, Left all right (?). When bending down, sometimes giddy and sick, must then have a rest of  $\frac{1}{4}$  or  $\frac{1}{2}$  hour before resuming his work. Out-patient clinic suggested cochlear deafness. Patient was referred for hearing tests.

## Audiometry

Right	Air C	57	64	54	65/66	96	x	x
	Bone C	24	33	28	24/33	43	x	x
	Rinne	-33	-31	-26	-41/-33	-53	x	x
Left	Air C	37	35	34	39/67	51	94	x
	Bone C	24	29	17	18/25	39	x	x
	Rinne	-13	-6	-17	-21/-42	-12	?	x

Tuning forks (e) Rinne Right -, Left ?, Schwabach Right (-), Left normal

(a<sup>1</sup>) Rinne Right ?, Left +, Schwabach Right (-), Left normal ?

Vestibular tests Directional Nystagmus Susceptibility to Left, according to cold/rotatory calculation, and especially to the result of "direct observation of directional Nystagmus susceptibility" [vide Records IX]

There was, following Left cold calorization, practically no nystagmus in end position to right, but definitely to Left. As vestibular abnormalities, meanwhile in progress of research work, were more frequently found with otosclerosis than with cochlear deafness, the differential diagnosis was left to X-rays. The diagnosis of the X-ray department, confirmed by Mr Watkyn-Thomas, was "The osseous labyrinths are not very clearly defined on either side, and on the left is an area of osteoporosis of the petrous bone above the labyrinth, which seems to have destroyed the outline of the superior semicircular canal".

# Contributions to Functional Pathology—IV

(iii) H. Sybill, 57; deaf since pregnancy 24 years ago.

Audiometry		x	x	x	x/x	x	x	x
Right	Air C	24	34	39	x/x	x	x	x
	Bone C.	60	72	87	95/95	100	x	x
Left	Air C	24	28	39	2/x	x	x	x
	Bone C.							
Rinne		-36	-44	-48	2/2	2	x	x

Caloric tests: 18° to c c right no response, left poor response.

Rotatory tests: 5 and 10 rotatory no nystagmus, no giddiness

X-rays Both sides very definite osseous changes

(b) Diagnosis "Otosclerosis" supported by history: since confinement, 3 cases, a (iii) and another two, both with definitely positive Paracusis.

Diagnosis "Otosclerosis" supported by Eddowes's syndrome; 1 case, D. Walter, 34. Has marked blue sclera. Fragility of bones with several brothers. One of the brothers fragility and deafness.

Audiometry		53	62	65	64/72	67	x	x	average Rinne -44
Right	Air	53	62	61	66/69	60	x	x	average Rinne -47
	Air	59	62	61					
Tuning forks:		(e) Rinne both -	Schwabach both +						
		(a <sup>1</sup> ) Rinne both -	Schwabach both normal						

(c) b.c.o. with history suggestive of neuritis VIIIth nerve.

(i) F. Margaret, 63; diabetes 10 years, deafness several years.

Audiometry		54	60	61	68/75	85	x	x
Right	Air	54	60	61	65/77	75	95	x
	Air	52	53	55				
Tuning forks:		(e) Rinne both -	Schwabach both normal (?)					
		(a <sup>1</sup> ) Rinne both -	Schwabach normal					

Vestibular tests: both sides abnormal. End>Mid, and directional Nystagmus susceptibility to Right, diagnosed by direct observation

(ii) P. Mrs., 74; deafness following measles 30 years ago The same course of deafness following measles with one sister (no middle-ear suppuration).

Audiometry		57	63	63	68/82	83	73	x average Rinne	-53
Right	Air C.	57	63	63	78/83	68	83	x average Rinne	-46
Left	Air C	57	55	68					
Tuning forks		(e) Rinne both	-, Schwabach normal						
		(a <sup>1</sup> ) Rinne both	-, Schwabach (-)						

(d) Cases of particular significance.

(i) vide "Primordial" cases, one side b.c.o., other side b.c.d [vide Record IV 2 (i)].

(ii) Coincidence of b.c.o. with suspected spasm in the tympanic muscles. P. Arthur, 63; sharp blow with metal handle right temple, 7 days ago. Bad hearing before, since then worse Family history positive.

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## Audiometry

Right Air 60 69 71 70/77 89 × × average Rinne -45  
 Left Air × 73 76 80/93 94 95 × average Rinne -57  
 Tuning forks (a<sup>2</sup>) Rinne both -, Schwabach Right ++, Left +, even in Weber's test (a<sup>2</sup>) was heard longer than normal

Mr Watkyn-Thomas noted a strange retraction at the right drumhead which he was inclined to attribute to some spasm in the musculus tensor tympani (Regular physiological contractions of the muscle are not associated with changed positions of the drumhead)

(iii) b.c.o. identified only on Bone Conduction.

R. Alfred, 58; deafness gradually 23 years. Family +. Paracusis +. Left ear noise, beating of the pulse.

## Audiometry

Right	Air C	×	×	79	84/91	96	95	×
	Bone C	14	19	21	29/52	×	×	×
Left	Rinne	?	?	-58	-59/-39	?	?	×
	Air C	×	×	×	105/110	×	×	×
	Bone C	18	24	27	40/65	×	×	×
	Rinne	?	?	?	-65/-45	×	×	×

Right typical b c o, Air C (and Bone C), left Air C only residua, but Bone Conduction specific b c o

## RECORD VIII

### FAMILY INVESTIGATIONS WITH HEREDITARY DEAFNESS

The number of seven family cases is too small to provide any conclusive results. They are reported, however, to indicate some new ways of family investigation with hereditary deafness. The writer's Provocative Test seems to be one way of diagnosis of latent deafness in hereditary families, another promising way, the writer's vestibular diagnosis of congenital deafness, could so far not be followed up on a satisfactory scale.

#### (i) Family V—n.

V—n Peter, 2<sup>3</sup>/<sub>4</sub>, suspected deaf-mutism.

Parents' first child, lively, intelligent Audiometry probably not heard Very intensely sounded c<sup>4</sup> Edelmann fork certainly not heard no response of attention, no palpebral reflex Ugly voice of deaf-mutism -Labyrinth chair Following 10 rotations, both directions gross Nystagmus, and post-rotatory unsteadiness -*Diagnosis* Congenital deaf-mutism

Parents' Question What chance of deafness with a second child? "No family deafness" Parents' hearing "normal" subjectively, Objective findings -

(a) Mother V—n, Molly, 27.

Audiom. index Right 27, Left 23 db Routine average Rinne right -2, left -1  
 -- Provocative Rinne Right +3, Left +3 --Tuning forks (steppage tests) normal  
 -- Vestibular tests caloric normal, Mid Nystagmus>End Nystagmus (20° 10 c c)

(b) Father V—n, Alfred, 31. No intermarriage.

Audiom. index Right 32, Left 33<sup>1</sup>/<sub>2</sub> Routine average Rinne right -12, left -12  
 -- Provocative Rinne Right +6, Left ca +12 --Tuning forks (steppage tests) normal --Vestibular tests Right End>Mid, directional Nystagmus susceptibility to Right (method of direct observation) [Left ear was not tested, because vestibular abnormality was, beyond doubt, ascertained]

## Contributions to Functional Pathology—IV

*Summary:* Parent's hearing practically normal, upon routine tests. Special tests' result is, however:

Mother: provocative tests beyond range of normality.

Father: audiometric Routine Rinne slightly suggestive of physiological negative Rinne. Provocative Rinne both ears definitely abnormal Vestibular tests abnormal.

*Conclusions.* Definite latent deafness with father, with indication of perivestibular osseous changes Latent deafness of mother suggestive.

*Hereditary Prognosis* for second child, dubious, ad malum vergens in view of abnormalities possibly in both parents.

(ii) Family L—n.

L—n Walter, 8 months.

Mother is worried about child's hearing No post natal serious fever disease, especially no meningitis —Intensely sounded c<sup>4</sup> Edelmann fork no response, including palpebral reflex —Labyrinth chair 5, and 10 rotations no response —*Diagnosis* probably no congenital, but ante-natally acquired deafness

(a) Mother L—n Elly, 23. No family deafness.

*Audiom. Index* Right 27, Left 25 db Routine average Rinne right -13, left -6  
—Provocative Rinne Right  $\pm 0$ , Left -3 —Caloric tests (only right done) *Mic*  
Nystagmus > End Nystagmus (normal) Rotatory tests each direction normal

(b) Father L—n Hans, 33. No family deafness.

*Audiom. Index* Right 25, Left 20 db Routine average Rinne right -11 left  $\pm 0$   
—Provocative Rinne Right -1, Left -4½ —Tuning forks (steppage tests) c<sup>3</sup>,  
right, first period only 55%, otherwise normal —No vestibular tests

*Summary:* Mother normal, father normal (apart from slight auditory inefficiency right, without regard to the unknown vestibular tests)

*Conclusions:* Absence of latent congenital deafness with mother, and probably with father, confirms the diagnosis of the child's ante-natally acquired deafness. Question of hereditary Prognosis, such as with case (i), does not arise.

(iii) Family P—l.

P—l Rosina, 15½; deaf-mutism since 13 years.

Intelligent mother denies categorically that the child was born deaf It started walking and talking in the same way as the mother's elder children did up to an accident at the age of 2½ years (1931). Mother insisted on following history written on my request "Child was in push chair which shut up and right thumb was cut through at middle joint Was taken to a Children's Hospital and attended to Was shaking and trembling for 1 hour after the accident A few months after, the speech was noticed to be slowly going, but was put down to shock following accident 1931—Hospital found nothing wrong only shock 1936—Nose, Throat and Ear Hospital found only mental shock "

Audiometry only 512, highest intensity, heard nothing else

Tuning forks. very poor residua, high scale little better than low

Vestibular tests. 5 rotations each direction full response

*Comment:* In antagonism to the general scepticism against a mother's history on the effect of her baby's accident I dare say that the mother is

right in our case. According to, probably, congenital lack of normal resistance in the organ of Corti, or in the labyrinthine capsule, a relatively small accident has broken the power of resistance, and initiated progressive deafness.

(a<sup>1</sup>) Mother P—1 Isabel, 54; good hearing, no family deafness. *Intermarriage* between her mother and father.

Audiom. Index: Right 31, Left 35½ db; average routine Rinne right -2, left -12.  
Provocative Rinne right +3, left +7.

Vestibular tests: normal: caloric both ears Mid > End Nystagmus.

(a<sup>2</sup>) Mother's daughter Betty, 25; step-sister of deaf-mute child. Hearing "good".

Audiom. index: Right 19½, Left 21; average routine Rinne right -1, left -7, however the individual Rinne (8192) right +22, left -17.

Provocative Rinne: right +3, left +2.

Vestibular tests: both ears caloric: End > Mid Nystagmus directional Nystagmus susceptibility to Right upon direct observation, and calor./rotat. calculation.

(a<sup>3</sup>) Mother's son Geoffrey, 31, step-brother of deaf-mute child; Hearing "good".

Audiom. index: Right 24, Left 20; aver. routine Rinne right -7, left -1.

Provocative Rinne: right ca +3, left ca -3.

Vestibular tests: both ears caloric: End > Mid Nystagmus directional Nystagmus susceptibility to Left upon direct observation, and calor./rotat. calculation.

*Summary:* From the deaf-mute child's mother's-side,

(a<sup>1</sup>) Mother shows abnormal Provocative Rinne.

(a<sup>2</sup>) Mother's daughter, slightly abnormal Provocative Rinne, and vestibular abnormality.

(a<sup>3</sup>) Mother's son, abnormal Rinne one side, and vestibular abnormality.

*Conclusion:* With 3 family members, whose routine tests show no abnormality, more or less definite abnormalities were detected by our special tests.

(b) Father, P—1 John, 54; Hearing not too good 6 or 7 years: Humming noises both ears. Noisy work shop.

Audiom. index: Right 539/8=67, Left 454/8=57; average routine Rinne right -29, left -23.

Provocative Rinne: left +2 (right not tested).

Vestibular tests (caloric), only left done: Mid=End Nystagmus. No directional Nystagmus susceptibility, upon direct observation (but only caloric left ear!)

*Summary:* not conclusive, but suggestive of congenital vulnerability (possibly manifested by professional acoustic strain).

## GENERAL CONCLUSION ON (iii)

The congenital character of the child's deaf-mutism seems to be confirmed by definite hereditary signs on mother's side, and suggestive signs in the father's tests. Intermarriage, on mother's side, is called to mind.

# Contributions to Functional Pathology—IV

## (iv) Family M—e

M—e, Colette, 16, deafness first noticed, when school started  
Speaking and walking began normally

She is one of the 2 cases of a c d (apic cochlear deafness) [*vide* Record VI A (i)]

Vestibular tests both sides normal [Mid Nystagmus > End]

(a) Father, Robert, 48 Hearing not sharp, when tired, 10 or 15  
years Grandmother was fairly deaf, when over 60

### Audiometry

Right	{ Air C	43	46	36	44/45	37	55	66	average Rinne ~18
	{ Bone C	x	34	15	9/27	30	51	x	
Left	{ Air C	35	34	28	26/37	42	63	x	average Rinne -7
	{ Bone C	x	29	17	7/37	40	?	x	

Provocative Rinne right ca +5 left -4½

Vestibular tests with 16° 5 c c and 10 c c both ears no Nystagmus rotatory tests  
subnormal excitability

*Individual conclusion* Typical cochlear deafness upon routine audiometry but highly  
suggestive of otosclerotic strain (definitely vestibular subnormal excitability)

(b) Mother, Yvonne, 46 Hearing "excellent"

Audiom index Right 187/8=23½ Left 191/8=24 average routine Rinne right -5  
left -9½

Provocative Rinne right ca -4½ however slight shifting to the left left < +7

Vestibular tests caloric 16° 5 c c directional Nystagmus susceptibility to right  
upon direct observation

*Individual conclusions* suggestive of latent deafness with signs of otosclerotic strain  
(directional Nystagmus susceptibility)

## GENERAL CONCLUSION ON (iv)

The early start of progressive cochlear deafness of the girl is plausible  
with regard to manifested heredity on father's, and to latent heredity  
on mother's side The dual heredity was shown only by our special tests

## (v) Family E—n

E—n Jean, 13 Deafness slowly growing, first noticed after bomb  
blast, 3 years ago No family deafness known

Audiom index Right 480/7=68½ Left 532/8=66½ db average routine Rinne  
right -37 left -39

Tuning forks (e) Rinne both ears negative Schwabach both positive

(a') Rinne both negative Schwabach both positive

*Individual diagnosis* Otosclerosis

## Family

(a) Mother, 48 Hearing "good"

### Audiometry

Right	Air C	35	28	27	23/34	30	24	33
			average Rinne			-6		
Left	Air C	22	23	19	25/35	24	30	52
			average Rinne			-5		

Provocative Rinne right -2 left +5

Vestibular tests (16° 10 c c) both ears especially right End > Mid Nystagmus

*Individual diagnosis* some abnormality with routine audiometry left (1024) and  
especially (819°) associated with abnormal provocative Rinne left Vestibular tests are  
suggestive of otosclerotic changes

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(b) Brother David, 12. Hearing "good".

Audiom. index : Right  $349/8=43\frac{1}{2}$ , Left  $191/8=24$ ; average routine Rinne right -17, left  $-8\frac{1}{2}$ .

Tuning Fork steppage tests : left nearly normal, right the "first periods" much abnormal, e.g. with fork c (250 d.u.) 18% of normal.

Provocative Tests : right -3, left +6.

Vestibular Tests : probably subnormal excitability, but unconvulsive.

*Individual diagnosis* : Auditory and vestibular abnormalities, the latter suggestive of otosclerotic early changes.

(c) Brother Reginald, 18. Hearing "good",

Audiom. index : Right  $143/8=18$ , Left  $122/8=15$ ; average routine Rinne right -6, left  $\pm 0$ .

Provocative tests : both ears normal, i.e. negative provocative Rinne.

Vestibular tests : ( $16\frac{1}{2}^{\circ}$  5 c.c.) right normal; left 5 and 10 c.c. no, 20 c.c. poor response. — Post-rotatory Nystagmus to left > to right. — Directional Nystagmus susceptibility to Left (upon calculative calor./rotat.).

*Individual diagnosis* : Routine and special auditory tests normal, vestibular tests suggestive of latent otosclerotic changes.

## GENERAL CONCLUSIONS ON (v)

Some objective, especially vestibular, abnormalities with subjectively normal hearing in next of kin of a young otosclerotic girl.

(vi) Family R—n

R—n Alan, 12; deaf 2 years gradually.

Audiometry

Right	{ Air C.	+	x	85	86/83	77	84	x
	{ Bone C.	x	x	31	27/38	25	30	42
Left	{ Air C.	40	39	38	34/42	51	42	31
	{ Bone C.	x	31	14	1/18	11	13	29

Provocative tests : unreliable. — No vestibular tests.

*Individual diagnosis* : suggestive of a.c.o. (apic. cochlear otosclerosis).

(a) Mother, 33; hearing "normal".

Audiom. index : Right  $284/8=35\frac{1}{2}$ , Left  $238/8=30$ ; average routine Rinne right -9, left -5; Provocative Rinne : right  $\pm 0$ , left -3.

Vestibular tests still missing, and father's tests not yet available.

(vii) Family Sp—r

Sp—r Bessie, 28; gradually worse 15 years. More noises after first child 5 years ago. Now, 5th month of pregnancy.

Audiom. index : Right  $465/7=66\frac{1}{2}$ , Left  $424/7=60\frac{1}{2}$ .

Tuning fork tests, 6 months ago, before present pregnancy : fork (a<sup>1</sup>) Rinne both negative, Schwabach both normal; now, 5th month pregnancy (a<sup>1</sup>) Schwabach right +, left + "very loud".

*Individual diagnosis* : Classical Otosclerosis.

(a) Mother, 50; deaf, following pregnancy 25 years ago.

Tuning Forks : Otosclerosis.

(b) Sister, 21; hearing "good".

Audiom. index : Right  $201/8=25$ , Left  $167/8=21$ ; average routine Rinne right -8, left -2. Provocative Rinne : right < +6, left ca +8.

Vestibular tests : missing.

*Individual diagnosis* : Latent abnormality ? (provocative Rinne<sup>1</sup>) ; so far unqualified (vestibular tests missing).

## Contributions to Functional Pathology—IV

(c) Sp—r, Mr, 31, husband of Sp—r Bessie, "good hearing", no family history

Audiom index Right 130/8—16 Left 129/8=16 average routine Rinne right  $\pm 0$  left +2 Provocative Rinne right -9 left -11 (normal) no vestibular tests  
*Individual diagnosis* probably normal (in spite of vestibular tests missing)

*Conclusion on prognosis* of hearing of the expected child of Mrs Sp—r Bessie and (c)

Child seems to be exposed to hereditary abnormalities only on mother's [*vide* (a) and (b)], not on father's side

### RECORD IX

Examples of TESTS of DIRECTIONAL NYSTAGMUS SUSCEPTIBILITY in cases of Progressive Congenital Deafness

Mostly it is sufficient to do one cold minimum caloric test for each side, instead of two each side by applying the cold and warm tests. The patient lying, head slightly elevated, is irrigated first, say right  $20^{\circ} 5$  c c, with Bartels' 20 drop glasses. When no more Nystagmus, or only still uncertain eye movement, is present, the glasses are taken off, and, now, the Nystagmus, if re-appearing in end position, is *directly* observed, (not only calculated such as with the cold/warm calorization!), and is registered both in the left (typical) *and* right (paradoxical) end position —Nystagmus in our case—right cold calorization—means, when appearing to the left normal behaviour, when appearing to right and left on a fairly equal scale directional susceptibility to right very suggestive, when appearing to right > left, gross directional Nystagmus susceptibility to right upon direct observation. After a due interval of at least 5 minutes, the same test must be done on the left ear. The results of right and left compensate each other, and provide a definite diagnosis in the majority of cases —When diagnosis is uncertain, rotatory tests are necessary, if possible on the labyrinth chair, active rotation of the standing patient is a substitute 2, or 3, (or 5) rotations, according to the response, yield very often a marked difference between right/left. The difference can be used for the "cold/rotatory" calculation of directional Nystagmus susceptibility, such as illustrated below sub (2) with case R Elsa —Figures of caloric tests, with glasses on, should not be compared with rotatory tests in end position, and *vice versa*

Only rarely cold/warm calculation cannot be dispensed with, then warm calorization is needed, a test disliked by many patients, and by the writer because its accuracy seems to be problematic

In a first series of cases reported in this paper, the *calculation* of directional nystagmus susceptibility, in a second series the *direct observation*, the writer's original method, set up 25 years ago, was systematically followed up



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### Calculation of Directional Nystagmus Susceptibility.

(1) Principles of Hallpike-Vogel's test are known [*vide* writer's criticism in *J. Laryng. and Otol.*, 1943, lviii, 167].

The diagnostic conclusion, per exclusionem, by comparing the results of cold and warm calorization, suggested by Vogel, was referred to the writer's method which compares the results of

(2) Cold/rotatory tests. The calculation is as follows:

R. Elsa, 56; otosclerosis.

		Cold test	
Right		Mid pos.	Left
limit: 150"		20 Diop. glasses	short response 20-30 sec.
limit: 360"		End pos.	240"
only SM's		Warm test	
		Mid pos.	only SM's
210"		End pos.	300"

**Conclusion:** End > Mid Nystagmus Directional Preponderance to Left.

#### Labyrinth Chair.

2 rotatory to Left	2 rotatory to Right
poor response	16 jerks to Left
(only SM's)	

### Direct observation of Nystagmus susceptibility.

S. Dorothy, 27; advanced otosclerosis.

caloris. Right ear	cold test mid posit. 20 Diop.	caloris Left ear
limit: 120"		limit: 60"
right ← Nyst. → Left		right ← Nyst. → left
? 20" (+)		+ 10" 0
? 60" +		+ 30" 0
(+) 90" +		+ 60" 0
(+) 120" +		> + 90" 0
+ 150" (+)		(+) 120" 0
+ 180" (+)		+ 150" 0
+ 240" (+)		+ 180" 0
+ 300" > (+)		> (+) 240" ?

#### Labyrinth Chair

Left	Right
2 rotat. to	
<40 jerks to right	6 or 7 jerks to left
The "paradoxical" nystagmus to right, following right cold calorization, upon direct observations is: directional preponderance to right. This corresponds with cold/rotatory calculation (by comparing, of course, only the typical directions in end position, such as Nystagmus to Left following Right cold calorization).	

Not only directional nystagmus susceptibility, but also general nystagmus susceptibility—with or without directional preponderance—

## Contributions to Functional Pathology—IV

can be noted with otosclerosis or other cases of vestibular abnormality. The general susceptibility is undetectable to tests of calculation, which, when exclusively carried out, do not tell the full and accurate story of nystagmus susceptibility. (For this and other reasons the writer does not trust the cold/warm tests, and his own cold/rotatory calculation neither. The well controllable and simple test of direct observation should be generally adopted.)

Example of *general—bi-directional—nystagmus susceptibility* with *directional preponderance* (to right).

Ch. Bessy, 27, otosclerosis.

caloris	Right ear	Cold test	caloris	Left ear	Labyrinth chair
	60° o	mid posit.	60° a few jerks		2 rotat
		(glasses)	90° almost over		Left
					18 jerks
					right
					Right
					practi-
					cally nil
right←Nyst→left		end posit	right←Nyst→left		
+ 15° o			+ 10/15° o		[The diagnosis of associated directional preponderance to right is in accordance with cold/rotatory calculation, by duly comparing only the typical directions in post-caloric end position of the eyes]
+ 60° o			+ 60° o		
+ 120° o			+ 120° (+)		
+ 180° o			+ 180° (+)		
(+) 240° o			+ 240° > (+)		
(+) 300° o			+ 300° (+)		
+ 360° o			+ 360° (+)		
etc.			etc.		

### RECORD X

#### X-RAY DIAGNOSIS OF OTOSCLEROSIS

Three cases were mentioned with Record VII (i), (ii), (iii) on basal cochlear otosclerosis. In two further cases the dubious diagnosis could be established by X-rays.

M. Rosa, 34; much advanced deafness, very bad bone conduction: otosclerosis? cochlear deafness?

Vestibular tests were in favour of otosclerosis (definitely subnormal caloric excitability).

X-ray: "Very considerable zone of dense bone surrounding the superior semicircular canal on each side, supporting diagnosis of otosclerosis".

H. Margaret, 32; very beginning of otosclerosis. Vestibular signs more suggestive than almost negligible loss of hearing.

X-rays: supporting diagnosis of otosclerosis [*vide* introductory case Record I].

The X-rays may often be useful in the diagnosis of established otosclerotic osseous changes. On the other hand M. Weber stresses the point, that early microscopical otosclerotic changes cannot be identified

# F. Kobrak

by X-rays, which is not in accordance with S. A. Jenkins who found X-ray changes in the labyrinth without any clinical signs.

Combination of vestibular + X-ray examinations, apart from auditory tests, is indicated in dubious cases of progressive congenital deafness, and might be useful by supporting or checking each other in cases, in which X-ray and vestibular changes are markedly unilateral.

## RECORD XI

### TABLES OF PROGNOSIS with six types of *Progressive Congenital Deafness*

TABLE I

illustrating the "Order of Congenital types" of deafness based on the Scale of Decibel Loss—*Audiometric Index of Deafness*.

Auditory Index of deafness (db. loss)	c.d. (except b.c.d.)	b.c.d.	cl.o.	n.cl.o.	c.o. (except b.c.o.)	b.c.o.
>40	2	17	3	0	2	1
40—>50	9	23	12	2	1	6
50—>60	4	14	16	15	10	9
60—>70	5	7	17	28	10	14
70—>80	0	2	5	8	9	26
<80	2	2	0	0	4	13
	22 ears	65 ears	53 ears	53 ears	36 ears	69 ears

Percentage of decibel loss with these 298 ears related to the six types of congen. deafness.

>40	9%	26%	6%	0%	5%	1%
40—>50	41%	35%	23%	4%	3%	9%
50—>60	18%	22%	30%	28%	28%	13%
60—>70	24%	11%	32%	53%	28%	20%
70—>80	0%	3%	9%	15%	25%	38%
80	8%	3%	0%	0%	11%	19%
	100% c.d.* (except b.c.d.)	100% b.c.d.*	100% cl.o.*	100% n.cl.o.*	100% c.o.* (except b.c.o.)	100% b.c.o.*

\* c.d.=cochlear deafness; b.c.d.=basal cochlear deafness; cl.o.=classical otosclerosis; n.cl.o.=non-classical otosclerosis; c.o.=cochlear otosclerosis; b.c.o.=basal cochlear otosclerosis.

# Contributions to Functional Pathology—IV

The prognosis of c.l.o. seems to be definitely better than that of the other types of otosclerosis, even of n.c.l.o. The latter is, only apparently, non-cochlear. There is no apparent cochlear paralysis. However, there seems already to be a state of abnormal cochlear irritation or irritability. From this point of view, the n.c.l.o. should be regarded as an irritant c.o., the c.o. as a paralysis c.o. But taking the prevailing clinical point I prefer to suggest the terms: n.c.l.o. and c.o.

It is obvious how different the table I (and also II) would look like, if b.c.d. and b.c.o., as usually, would be mixed up.

TABLE II

Percentage of Otosclerosis, and of Progressive Cochlear Deafness with reference to age.

(a) age	119 cases of Otosclerosis		47 cases of Prog Coch Df		(b) 166 cases of Otosclerosis + Progressive Cochlear Deafness (= 100%)		(c) Cut out of Table (a)		
	No	%	No	%	Out of these 100% Otoscl	Pro Coch Deafness	ages	%	Cochl Dfn
>30	39	33	8	17	83%	17%			
30—>40	37	31	11	23.5	77%	23%	>30 and 30—40	64	40.5
40—>50	19	16	11	23.5	63.5%	36.5%			
50—>60	18	15	10	21	55.5%	44.5%	60—70 and <70	5	15
60—>70	5	4	5	11	50%	50%			
70—<70	1	1	2	4	33½%	66½%			
	= 119	= 100%					This is reflected in the % figures of Table (b)		

*Comment.* The three tables show that the percentage of all Otosclerosis cases referred to the age at the unselected term of examination decreases with growing age, which can not be related, at least up to the age of 60, to the factor that out patient's clinics are less attended by people of higher age. Table (b) proves that an intrinsic factor is in operation. Otherwise there would not be the definite difference between Otosclerosis and Progressive Cochlear Deafness (also illustrated on Table (c)). This is obviously dependant on the factor, that the capacity of the cochlear nerve is being worn out due to the passive factor of gradual increase in congenital lack of resistance,—partly associated with "presbycusis"—whereas the abnormal active changes in the labyrinthine capsula, possibly originating from the end of the second year of life, are in gradual decrease such as most of physical activities of the human body. The *prognosis* has, therefore to consider, on the one hand, in a case of progressive cochlear deafness of, say, 40,

# TEMPORARY DEAFNESS DUE TO GUNFIRE

By N. E. MURRAY and G. REID (Captain A.A.M.C.)

## 1. Summary

1. EXPOSURE to gunblast which is not of sufficient severity to rupture the eardrums, causes inner-ear deafness which affects mainly the higher frequencies, but may, if the exposure is severe, extend as low as 256 c.p.s.

2. The magnitude of the exposure necessary to produce a given degree of hearing loss varies with the individual; but severe effects (i.e. with peak losses of from 55 to 85 Db.) were commonly caused by exposures which were mild compared with what may be expected in action.

3. Measurement of blast pressure in gun crew positions, indicated that the amount of damage to hearing a gun is liable to cause, runs parallel, roughly, with the peak blast pressure.

4. Of those guns which were tested, serious hearing loss was caused by the 17 Pr., the 18 Pr., in a concrete emplacement, the short 25 Pr., the 3.7 inch A.A. gun, and the mortars, especially the short 3 inch type. Peak pressures at the positions where this loss was caused, ranged from  $1\frac{1}{2}$  to 8 pounds per square inch.

5. Rupture of the eardrum occurred in position 1 of the short 3 inch mortar, where the blast pressure was from 6 to 8 pounds per square inch.

6. Smaller pressures than these (e.g. about  $\frac{1}{4}$  pound per square inch from the rifle) will also cause severe loss of hearing, when a sufficient number of rounds is fired.

7. Loss of hearing lasted from a few hours to several days.

8. It is well known that the effect on hearing of inner-ear deafness is more noticeable at threshold than at higher levels. Usually in civil life threshold hearing is not very important, but with sentries, impairment of threshold hearing is of great importance, because they may be required to hear and localize the faintest of sounds. Of course when the deafness is as severe as occurred after firing the 17 Pr. the hearing of speech at ordinary conversation level will also be impaired.

9. Cotton wool plugs are an inadequate form of ear protection. The Protector, Eardrum Aust. Mk. 1 designed by the Acoustic Research Laboratory, gave complete protection for as severe an exposure as may reasonably be expected in action.

## 2. Introduction

1. Although a considerable amount of work has been done in recent years on temporary deafness following exposure to aeroplane and tank

# Temporary Deafness due to Gunfire

noise, almost no observations have been made on temporary deafness following exposure to gunblast. Reports of severe deafness following firing of typical Australian Army jungle guns, the 25 Pr short, and the short 3 inch mortar made a more detailed study, particularly of these guns, desirable.

2 This paper, which is the first of a series, is concerned with observations on *temporary* deafness occurring in members of guncrews, in experimental subjects exposed near guns, and in men firing small arms, together with the results of blast pressure measurements in gun crew positions. The amounts of temporary deafness resulting from the blast pressure from various guns and the practical aspect of these under operational conditions, are discussed. A second paper (see Ref 1, Reid, 1945) is concerned with the results of laboratory experiments and the elaboration of certain aspects not fully dealt with in this paper, and a third paper will report the results of a survey of the incidence of permanent hearing loss in artillery personnel.

## 3. Historical

1 It has long been recognized that many artillery men and those who are exposed to blast become permanently deaf. The earlier papers have been reviewed by Bunch in 1937. In recent years a number of new reports have appeared, Passe (1940), Scott (1940), Davis (1940), Craig (1940), Guild (1941), Alexander (1941), Schilling and Everley (1942), Fox (1943), Collins (1944), Taylor (1944), and Silcox and Schenk (1944). Some of these papers are concerned mainly with the rupture of the tympanic membrane, and indeed when one reviews the literature it appears that some authors appear unaware of the occurrence of inner ear deafness, and regard the detrimental effects of gunblast largely in terms of ruptured drums.

2 Bunch (1937), published audiograms of men permanently deafened as a result of blast from both large guns and small arms. Audiograms of naval or military personnel exposed to gunfire were also published by Schilling and Everley (1942), and by Taylor (1944). Collins (1944) in the Western Desert, and Silcox and Schenk (1944) at Guadalcanal described the hearing loss due to the effects of blast in battle casualties. These reports as well as others in the literature, show that except when the middle ear is damaged by trauma or subsequent infection, the deafness is of the so called, inner ear or nerve type, and involves mainly the higher frequencies.

3 Nearly all the reports on temporary traumatic deafness have been concerned with hearing loss following exposure to continuous noise. Dickson, Ewing and Littler (1939) and Campbell and Hargreaves (1940), published audiograms before and after exposure to aeroplane noise. Chamberlain (1942) examined four boilermakers before and after the day's work, and Schilling and Everley (1942) investigated the immediate

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## Temporary Deafness due to Gunfire

3. 6 inch coast gun Mk. 7 on Mk. 2 mounting (4)
4. 10 cwt. 6 Pr. Twin on mounting 6 Pr. Mk. 1 (3)
5. Bofors 40 mm. A.A. gun (1)
6. 9.2 inch B.L. coast gun Mk. 10 on mounting  
9.2 inch Mk. 7 (in turret) (2)
7. 9.2 inch B.L. coast gun Mk. 10 on mounting  
9.2 inch Mk. 7 (outside turret) (2)
8. 25 Pr. Mk. 2 (6)
9. 17 Pr. Tank Attack Gun with muzzle brake (3)
10. Short 25 Pr. gun (3)
11. 4 inch Q.F. naval gun (3)
12. Service rifle firing from hip (4)
13. Service rifle firing from shoulder (1)
14. Service rifle firing in an enclosed space (2)
15. 9 mm. calibre Owen gun (1)
16. 9 mm. calibre special submachine gun (3)
17. Vickers machine gun (3)
18. Bren machine gun (5)
19. 2 inch mortar (4)
20. 3 inch mortar (3)
21. 3 inch short mortar (2)

4. *Weapons investigated: blast pressure measurements.* These were made at the ear positions of gun crews around the following guns:

1. 25 Pr. Short
2. 25 Pr. Mk. 2
3. 17 Pr. Tank Attack
4. 6 Pr. Tank Attack
5. 3 inch Mortar—Long
6. 3 inch Mortar—Short
7. 2 inch Mortar
8. 3.7 inch Anti-Aircraft
9. Rifle

### 5. Observations

#### (a) SUBJECTIVE MEASUREMENTS

1a. The threshold of hearing of the subjects was tested before and after firing, with a Western Electric 6B Audiometer. Those subjects whose ears were obstructed with wax were excluded, or the wax was removed. For most of the experiments the ear drums were examined, a Rinne test done, and in a few instances the bone conduction audiometer threshold was determined before and after firing. In most cases the audiogram was taken between 10 and 20 minutes after firing ceased, and in all cases within the first hour. Sometimes tests were commenced



effect of exposure to Diesel engine noise in submarines. A more comprehensive investigation was carried out by Davis and his co-workers at Harvard (1942, 1943) on temporary deafness following exposure to loud tones and noise. This work, which was carried out under the auspices of the National Defense Research Committee of the U.S.A., was related mainly to problems connected with the exposure of military personnel to the noise of aeroplanes and armoured fighting vehicles.

4. On the other hand, experiments in which human subjects have been examined before and after exposure to blast are almost non-existent. Wilson (1942, 1944), described the temporary hearing loss in recruits after their first rifle shooting; but he was mainly concerned with determining, in any particular subject, whether the deafening effect of a pure tone would be a satisfactory method of predicting susceptibility to gunfire. Bunch (1938) described the onset of deafness after the explosion of a fire-cracker.

#### 4. Scope of Investigations .

1. *Location*: These Experiments were carried out at the Coastal Defence Batteries in the Sydney Area, the School of Artillery, Holsworthy, the Proof Ranges, Gellibrand and Port Wakefield, the Williamstown and Long Bay Rifle Ranges, and the Footscray Small Arms Factory. Acknowledgement is made to all who have facilitated the carrying out of observations in these places.

2. *No. of personnel examined*: Sixty four unprotected ears of 35 male subjects, were examined before and after firing artillery equipment, small arms and mortars. Twenty-eight of these subjects were army personnel; besides ourselves (G.R. and N.E.M.) there was a laboratory assistant (subject E.P.S.) and four others were medical students, one of whom had served in the artillery. The ages of the subjects ranged from 20 to 38 years. With the exception of ourselves and E.P.S., the men were examined, after exposure to usually only one of the guns. When both ears were not being exposed simultaneously, the unexposed ear was protected by the ear plug designed by this laboratory (Protector, Eardrum Aust. Mk. 1) and described in report No. 5 of this laboratory by Eccles and Murray (1943). *This is a neoprene synthetic rubber plug of oval cross section to conform to cross section of the external auditory meatus.* A tube of antiseptic lubricant (*merthiolate in a lanoline base*) is included with the plugs to guard against ear infections, especially in tropical areas.

3. *Weapons investigated: subjective measurements.* Subjects, the number of whom appear in the parentheses, were examined, before and after the firing of the following guns:

1. 3.7 inch A.A. gun (2)
2. 18 Pr. in emplacement for coast defence (3)

# Temporary Deafness due to Gunfire

- 3 6 inch coast gun Mk 7 on Mk 2 mounting (4)
- 4 10 cwt 6 Pr Twin on mounting 6 Pr Mk 1 (3)
- 5 Bofors 40 mm A A gun (1)
- 6 9 2 inch B L coast gun Mk 10 on mounting  
9 2 inch Mk 7 (in turret) (2)
- 7 9 2 inch B L coast gun Mk 10 on mounting  
9 2 inch Mk 7 (outside turret) (2)
- 8 25 Pr Mk 2 (6)
- 9 17 Pr Tank Attack Gun with muzzle brake (3)
- 10 Short 25 Pr gun (3)
- 11 4 inch Q F naval gun (3)
- 12 Service rifle firing from hip (4)
- 13 Service rifle firing from shoulder (1)
- 14 Service rifle firing in an enclosed space (2)
- 15 9 mm calibre Owen gun (1)
- 16 9 mm calibre special submachine gun (3)
- 17 Vickers machine gun (3)
- 18 Bren machine gun (5)
- 19 2 inch mortar (4)
- 20 3 inch mortar (3)
- 21 3 inch short mortar (2)

4 *Weapons investigated blast pressure measurements* These were made at the ear positions of gun crews around the following guns

- 1 25 Pr Short
- 2 25 Pr Mk 2
- 3 17 Pr Tank Attack
- 4 6 Pr Tank Attack
- 5 3 inch Mortar—Long
- 6 3 inch Mortar—Short
- 7 2 inch Mortar
- 8 3 7 inch Anti Aircraft
- 9 Rifle

## 5 Observations

### (a) SUBJECTIVE MEASUREMENTS

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as early as 2 minutes after exposure, and in a large number of experiments the recovery was followed by a series of audiograms extending over several days. When figures for loss of hearing are unqualified as to time, they may be regarded as being at a stage between 10 to 20 minutes after exposure.

2a. The following frequencies were tested: 128, 256, 512, 1024, 2048, 4096, 5793, 9747 cycles per second, and other frequencies when it appeared specially indicated. They were tested in ascending order beginning at 1024 c.p.s. and the remaining frequencies in descending order beginning at 512 c.p.s. With practised subjects the whole test could be carried out, for one ear, in 5 minutes. Thresholds were approached from the region heard to the region not heard, and the intensities recorded in 5 Db. steps. In the tables and illustrations the loss of hearing is represented relative to the subjects' own pre-exposure threshold, and not, unless otherwise indicated, to the zero of the audiometer.

#### (b) "AVERAGE" AND "PEAK" HEARING LOSS

1b. In the presentation of the results it was desirable to find a suitable value, which would express as simply as possible, the degree of hearing loss which had been produced in a subject, and which could be used for comparison purposes when hearing loss had been produced in one subject on separate occasions.

2b. It is discussed in a later paper, how with increase in the severity of an exposure to which an individual is subjected there is an increase in the loss of hearing as depicted in an audiogram, in both width and depth; that is, there is an increase in the maximum loss at any frequency, and the effect spreads to involve frequencies previously unaffected. Full details of these effects are shown in the figures included in this paper. (Ref. 1).

3b. To express simply in a single figure the magnitude of hearing loss involved, it is necessary to know how the hearing loss suffered reacts on the ability of the subject to hear orders directly, through earphones, or amplifying apparatus, and also on the ability to detect sounds, especially when he is used as a sentry in jungle warfare. The sounds for which it will be necessary to use threshold hearing acuity will, in general, be of high pitch, such as the snapping of a twig, brushing of leaves or undergrowth by approaching enemy. The effects on the hearing of speech are largely related to the "average" hearing loss in the range 500 to 4,000, although they are almost as closely related to the average loss in the range 500 to 8,000. Where the use of the hearing at threshold, such as for sentries, is taken into consideration, as well as the types and extent of hearing loss produced by gunfire, the best single parameter for "average" hearing loss is that taken over the range of

# Temporary Deafness due to Gunfire

4 octaves from 512 to 8192 cycles (This is a similar "average hearing loss" measurement to that used for calculating deafness following exposure to loud noise (Ref 17)) Some comparisons can, therefore, be made with this work as to the relative severity of loud tones and gun fire in producing deafness

2b The maximum hearing loss produced at any frequency through the range 128 to 8196 cycles may also be used as a simple measurement of hearing loss, the point at which the maximum hearing loss occurs differing with different people as shown in the audiograms This "peak loss" has an advantage in that the length of time required for recovery is a function of the maximum loss at any frequency rather than the extent of the loss in the frequency range Its value is also of use in the study of the onset of permanent deafness, which is related more to the peak loss at any frequency than to the average loss over the whole range Where a simple figure is necessary to explain the amount of hearing loss we have, in general, tabulated the "average hearing loss" and/or "peak loss" defined above

## (c) BLAST PRESSURE MEASUREMENTS—APPARATUS

1c The measurements were made by means of Piezo Electric Gauge similar to that used by the Road Research Laboratory, England This is a Piezo Electric Gauge having a face of approximately an inch diameter mounted in a steel block This gauge was mounted in a headpiece and held in position over the ear The electrical impulses from the gauge were conveyed through the cable to an amplifier and cathode ray tube where the blast wave trace was photographed by a Contax camera with an F2 lens The amplifier used was resistance capacity low frequency compensated the time constant of the circuit, two seconds was sufficient to pass the low frequency envelope of the blast wave, the upper frequency range extending approximately flat to 100 kc Three stages of amplification were used to give a sufficient output voltage for full deflection on the face of the cathode ray tube

2c Initially the single sweep was actuated by a gun mount switch which operated immediately on recoil of the gun barrel Later a pilot gauge was used ahead with the main gauge to initiate the sweep and switch on the beam of the cathode ray tube a few milliseconds before the blast wave reached the ear Calibration of the gauge for blast pressures was carried out in the laboratory by means of a small pressure chamber carrying a calibrated pressure gauge The pressure chamber was suddenly decompressed by bursting a diaphragm Check calibrations were carried out, in the field, by means of a stable oscillator, the output of which was checked and impressed on the input circuits, with the cable and gauge attached, through a voltage dividing network The frequency of the oscillator was chosen to facilitate its use also for time calibrations

## 6. Subjective Results

### (a) TEMPORARY HEARING LOSS OF MEN IN THE VICINITY OF GUNS.

1a. Audiograms of various subjects after exposure to most of the guns are illustrated in figure 1 (pages 99, 100, 101). These illustrations were chosen so as to show a selection as representative as possible of both weapons and ears. There were also many subjects who after exposure showed greater losses than those illustrated in figure 1 but these subjects had such permanent or unrecovered deafness before exposure that an audiogram showing the loss relative to the subjects' pre-exposure threshold would have been misleading. (See figure 2a, page 103).

2a. The hearing losses of the 35 unprotected subjects as well as of 2 others wearing cotton wool and one female subject are set out in table 5 in the appendix. Despite the variation in sensitivity from one subject to another, it can be stated that among the large weapons, which have been tested, the most serious effects were caused by the 17 Pr. with muzzle brake, the 18 Pr. in a concrete emplacement, the short 25 Pr. gun, the 3.7 inch A.A. gun, the mortars especially the short 3 inch type, and outside the turret of a 9.2 inch B.L. gun. With these guns comparatively few rounds produced in one or more subjects a peak loss of 55Db. or more at some frequency between 2048 and 8192 c.p.s. It will be shown later that these effects run roughly parallel with the magnitude of the peak blast pressure.

3a. The two worst positions at which subjects were exposed were at No. 2 position of the 17 Pr. T/A gun (7 rounds) and at No. 1 position of the 3-inch short mortar (2 rounds). In both cases peak losses of 85 Db. were produced, and the second of the two rounds from the mortar caused rupture of the eardrum. For the short 25 Pr., sensitive subjects were not exposed in the worst positions.

4a. It is likely that the other large weapons, particularly the 25 Pr., the 6 inch coast gun, the 4 inch Q.F. Naval gun, and the 40 mm. Bofors A.A. gun would produce greater degrees of hearing loss than were obtained in the experiments with these particular guns had exposures been more prolonged. The last named gun caused no effect in the one subject who was exposed; but tests could not be made until one hour after exposure. Guns such as the 9.2 inch, the twin 6 Pr., and the 4 inch Q.F. Naval guns in which the crews or some of them are protected by turrets produced negligible effects. Such as were recorded, are due either to open hatches, or possibly to the general high noise level. Nevertheless circumstances may occur when men are exposed outside turrets, such as, for example, on the bridge of a ship, and it should be noted that when subjects were exposed outside the turrets, deafness was produced even after the few rounds which were fired.

5a. Turning to the small arms, it was surprising to find that peak hearing losses of the order of 50 to 70 Db. were commonly produced,

# Temporary Deafness due to Gunfire

0 db = Normal pre-exposure threshold

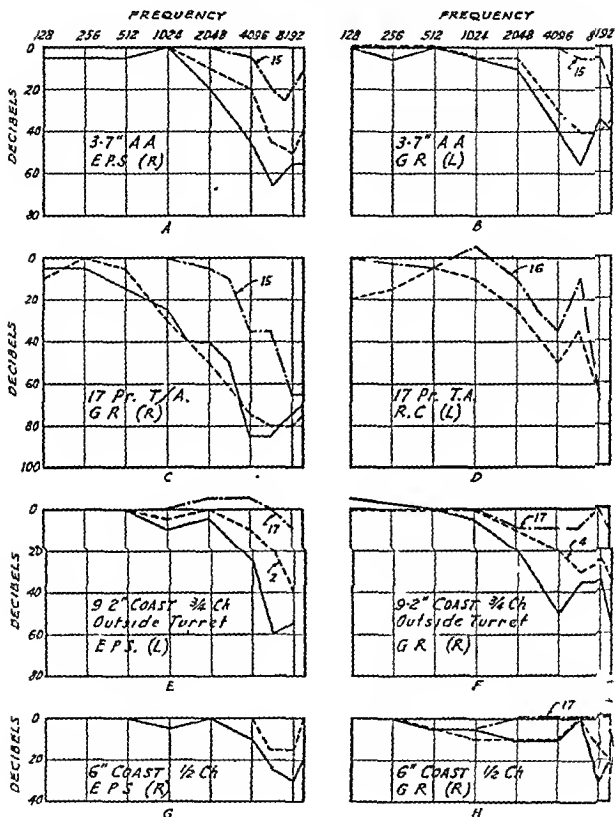


FIGURE 1

HEARING LOSS OF SUBJECTS  
AFTER EXPOSURE TO BLAST FROM VARIOUS GUNS

See Text & Table

- 10-20 minutes after exposure
- 1 hour after exposure
- · - · - 15-23 hours after (as indicated)

# N. E. Murray and G. Reid

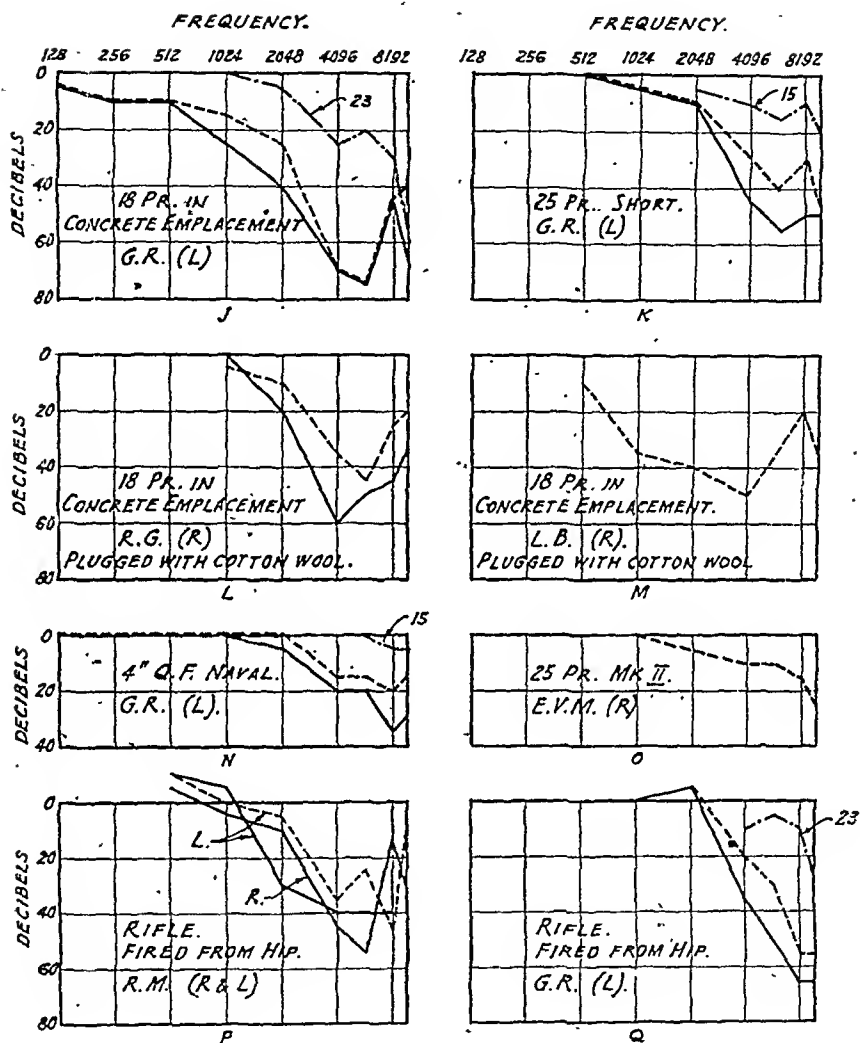


FIGURE 1. (CONTINUED)

HEARING LOSS OF SUBJECTS  
AFTER EXPOSURE TO BLAST FROM VARIOUS GUNS.  
See Text & Table.

- 10-20 minutes after exposure.
  - 1 hour after exposure.
  - · - · - 15-23 hours after, as indicated.
- 0 db = Normal pre-exposure threshold.

# Temporary Deafness due to Gunfire

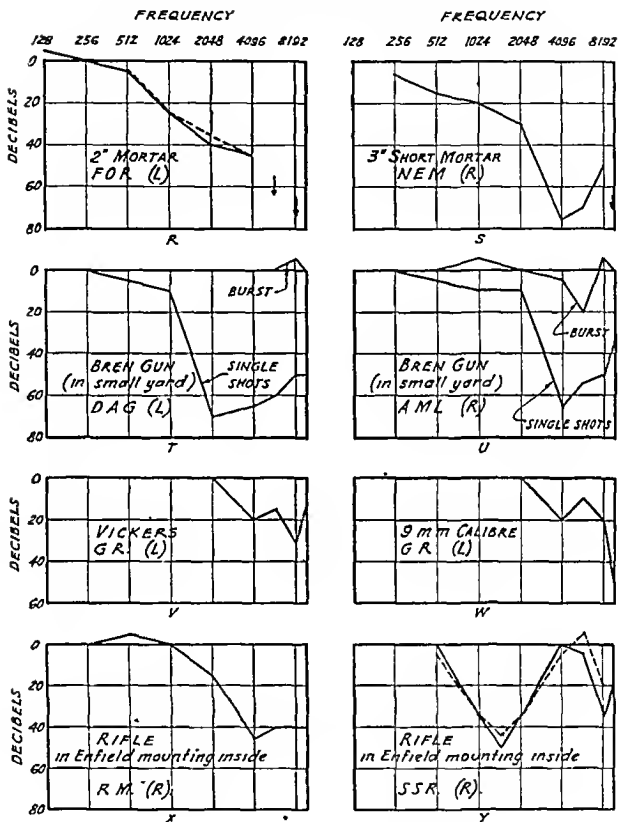


FIGURE 1 (CONTINUED)

HEARING LOSS OF SUBJECTS  
AFTER EXPOSURE TO BLAST FROM VARIOUS GUNS

See Text & Table

————— 10-20 mins after exposure

----- 1 hour after exposure

0 db = Normal pre-exposure threshold



## N. E. Murray and G. Reid

and that the rifle appeared for a given number of rounds more effective than a machine gun firing in a burst. One factor contributing to this result, is that when rounds are fired very rapidly (e.g. at 500/minute), the ear becomes protected after the first round of the series by means of the intra-aural reflex. When shots are separated by an interval of several seconds, each impulse reaches an ear which is unprotected, because the latent period of the intra-aural reflex is longer than the duration of the blast wave. These facts are illustrated by the audiograms of subjects exposed to firing of the Bren gun at two different rates of fire (see figure rT and rU).

6a. This study also shows that the small arms are particularly damaging when fired in a relatively enclosed space. In practice this occurs at proof ranges, but similar conditions may arise in action when there is house to house street fighting.

### (b) EFFECT OF FIRING ON SUBJECTS ALREADY PERMANENTLY DEAF.

rb. Usually those subjects who had much permanent deafness were unsuitable as experimental subjects. Generally speaking such subjects were relatively insensitive to blast. Nevertheless some gunners, already permanently deaf were made even more so after exposure. Figure 2a (page 103) shows the audiogram of the right ear of subjects F.J.B. who had been an infantryman for two years, after which for the past year he had been an artificer at a proof range. The upper and lower curves are, respectively the audiograms of this subject, before and after firing from the hip, 350 rounds from the rifle in a period of five hours. These curves are drawn relative to the zero of the audiometer. Figure 2b shows the audiogram of the right ear of subject who had been in a 25 Pr. gun crew for two years. The lower curve was made 45 minutes after exposure in position 2, to 18 rounds (15 charge 1, and 3 charge 3) of the 25 Pr. Mk. 2.

### (c) FREQUENCIES INVOLVED AND NATURE OF THE DEAFNESS

rc. It can be seen from figure 1 that with all of the guns the loss of hearing occurs mainly in the upper frequency range, usually with the peak loss between 4096 and 8192 c.p.s., sometimes between 2048 and 4096 c.p.s., and exceptionally between 1024 and 2048 as in figure IY. With severe exposures the effect spreads to involve lower frequencies. The variations in the shape of the audiogram which are met with are discussed more fully in a later paper. It suffices to state here that the variation depends on the subject himself and the number of rounds rather than on the type of gun (e.g. whether it causes subjectively, a "boom" or a "crack"). See section 8a.

2c. The Rinne test was always positive with the 512 fork, the result of this test as well as that of the bone conduction audiometric examinations, indicating that the deafness is of inner ear or nerve origin. When

# Temporary Deafness due to Gunfire

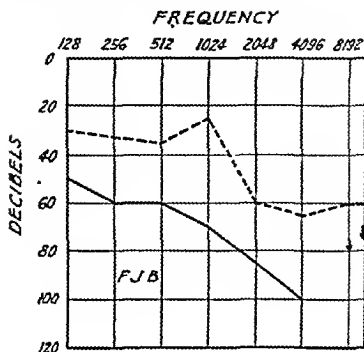


FIG 2 a.

BEFORE & AFTER 350 ROUNDS OF RIFLE

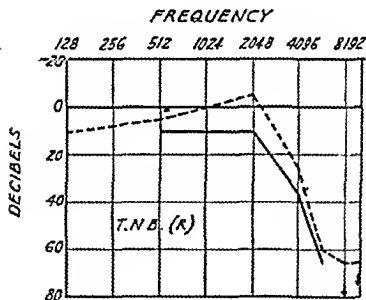


FIG 2 b

BEFORE & AFTER 18 ROUNDS OF 25 PDR

EFFECT OF GUN BLAST ON SUBJECTS  
ALREADY PERMANENTLY DEAF

----- BEFORE EXPOSURE

————— AFTER EXPOSURE

deafness was produced in ourselves we observed the phenomenon of loudness recruitment which is so characteristic of this kind of deafness. This is discussed in section 9. Quantitative observations of this phenomenon are fully reported by Davis *et al.* (ref. No. 17b), in deafness following exposure to loud noise.

3c. Occasionally there was a slight loss of about 10 to 15 decibels at 128 or 256 c.p.s. unassociated with a loss at 1024 c.p.s. or with a great loss in the higher frequencies. This is possibly attributable to the congestion of the eardrum, particularly along the handle of the malleus, which was sometimes observed.

#### (d) RUPTURE OF THE EARDRUM

1d. Gunners and subject G.R. had, early in these investigations been exposed to blast pressures of the order of 6-8 pounds per square inch, without rupture of the eardrum. As our experience grew we became reluctant to expose subjects unprotected, to such high pressures because of the degree of deafness which was caused and because reports were common, of gunners who suffered ruptured eardrums in gun positions where blast pressure was probably not greater than this value. Measurements of blast pressure in Position 1 of the Short 3 inch mortar had indicated that the peak blast pressure here, was of the same order (6-8 pounds per square inch) as that caused in some positions of the 17 Pr. gun where subjects had already been exposed. To minimize possible damage, it was decided to expose the right ear of N.E.M. in position 1 of the short mortar, and fire one round only, examining the ear before firing further rounds.

2d. One such round caused considerable pain and very severe tinnitus; an audiometric examination begun 5 minutes afterwards showed a peak loss of 75 Db. at 4096 c.p.s. (see figure 3a, page 105). After 80 minutes, exposure was made to a second round, which resulted in a further loss of 15 Db. at 5793 c.p.s.-bringing the peak loss to 85 Db. at this frequency. The audiogram is shown in figure 3a. There is no further change at 4096 or 2048 but there is a further loss of 10 Db. at 512 and 1024 c.p.s. This round resulted in rupture of the eardrum with bleeding from the ear, which may have accounted for the 10 Db. increase in the lower frequencies; but it is interesting to note that a Rinne test, 1 hour, 24 and 48 hours after exposure, was positive with a value of 20 seconds. The audiogram was roughly similar in shape to that following the first shot, and for some days the loudness recruitment characteristic of nerve deafness was clearly observable in the higher frequencies. In other words, in the absence of infection the deafness, despite the torn drum was largely of inner ear origin. Figure 3b shows the recovery curves from this exposure. The lag in the recovery from the lower frequencies (which usually are the first to recover, and recover in a few

# Temporary Deafness due to Gunfire

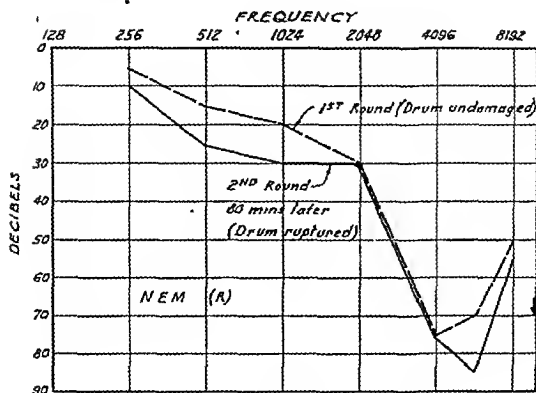


FIG 3 a DEAFNESS

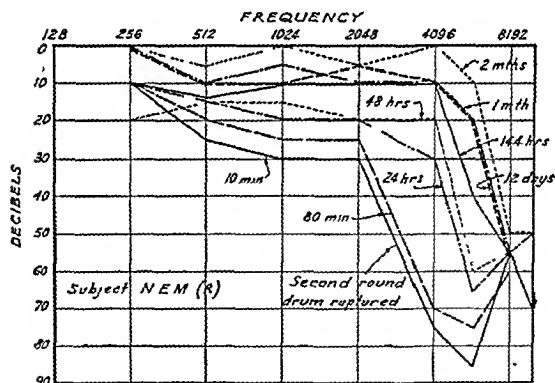


FIG 3 b. RECOVERY

**RUPTURED DRUM**  
**DEAFNESS & RECOVERY FROM 2 RDS OF 3" SHORT MORTAR.**

0 db = Normal pre-exposure threshold

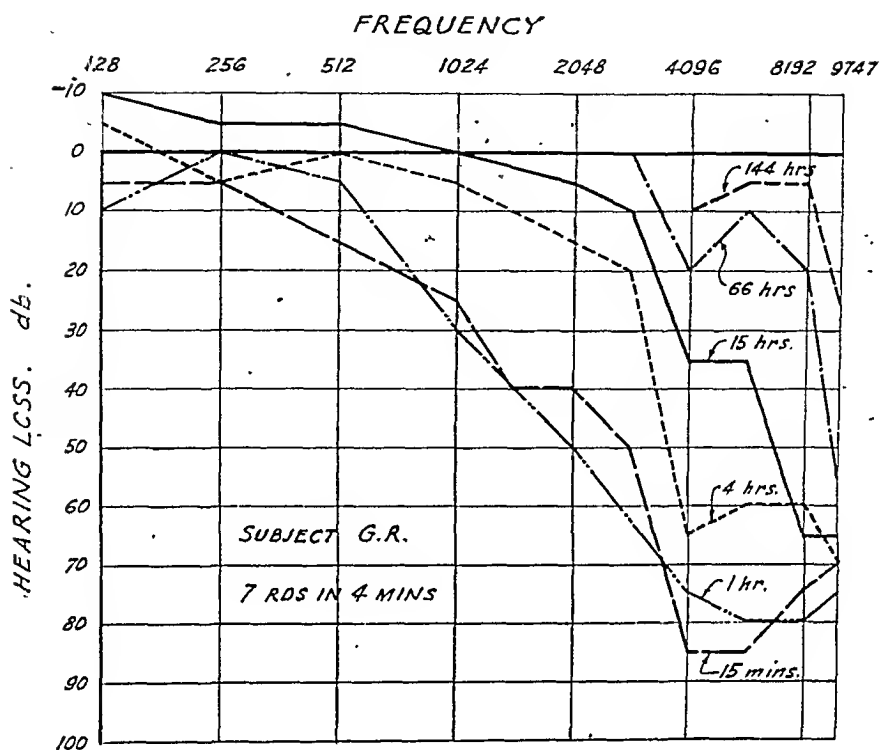


FIG. 4.

AUDIOGRAM AT VARYING PERIODS  
AFTER EXPOSURE TO 17 PDR. T/A GUN  
WITH MUZZLE BRAKE

## Temporary Deafness due to Gunfire

hours) is probably due to the ruptured eardrum. The upper curve of figure 3b shows the state of this ear 2 months after exposure. A peculiar feature is the complete lack of any real recovery at 8196 cycles, although there was almost complete recovery below this and some recovery at 9747. At the time of writing, two months after exposure, there remained a small clot on the eardrum sealing the rupture. The loss at 8196 shown persisting this time afterwards, may be considered permanent.

### (e) RECOVERY

1e This aspect is more fully discussed in a later paper. The curves in figures 1, 3 and 4, pages 99, 100, 101, 105, 106, indicate the way in which recovery occurs, and show that when the initial loss is severe deafness is still appreciable 15 to 23 hours after exposure. The audiograms of subject G R after exposure to 7 rounds of the 17 Pr T A gun with muzzle brake, and of N E M from 2 rounds 3 inch Short mortar, show that recovery was still incomplete six days afterwards. (See figure 3 and 4) The practical aspects of these recovery times are discussed in Section II, page 118.

### (f) VARIATION IN SENSITIVITY FROM SUBJECT TO SUBJECT

1f It is apparent from an examination of table 5 in the appendix that there is considerable variation in sensitivity among different subjects. For example the figures for hearing loss from the Long 3 inch mortar (see Appendix) are unimpressive, despite the fact, as will be shown later, that the blast pressure was of an order comparable with that which had caused considerable hearing loss in other subjects. The subjects available in the more severe positions for this experiment were relatively insensitive, and only four rounds were fired. In contrast to this result, the 2 inch mortar (see Appendix) caused considerable loss of hearing in the sensitive subjects who happened to be available on that occasion, despite the much lower blast pressure which is produced.

2f For this reason and because of the fact that the number of rounds and rate of fire were not standardized, it was not possible to compare the effects of various guns and at various gun positions, except in a general way. With the exception of ourselves and E P S, subjects were usually exposed to only one of the gun positions. Sufficient data, however, was accumulated, from the records of hearing losses of these and other suitable subjects, to clearly indicate which were the effects likely to be caused by the various weapons, and to correlate such observations with blast pressure measurements. By this means it becomes possible to state that a weapon, such as the 3 inch Long mortar will commonly produce serious loss of hearing, despite the fact that the experimental subjects exposed to the blast from it, were unaffected in the particular experiment reported here.

(g) HEARING LOSS FROM VARIOUS GUNS FOR SAME SUBJECT

1g. A comparison of the effects of a large number of exposures can most satisfactorily be made from the study of the records of a single subject. In table 1, below, the average and peak losses sustained by subject G.R. are set out. It should, however, be noted that a decrease in

TABLE I  
HEARING LOSS FROM VARIOUS GUNS FOR SAME SUBJECT (G.R.)

Gun, Position and Ear	Rounds per time	Hearing Loss Db.		Date
		Average 512-8196 c.p.s.	Peak	
17 Pr. with muzzle brake Pos. 2, R. ear	7/4 mins.	49	85	29.6.44
18 Pr. in concrete emplacement Pos. 1, L. ear	20/40 mins.	32	75	17.6.44
25 Pr. short Pos. 1, and 4, L. ear	10/110 mins.	22	55	7.7.44
9.2" B.L., outside turret, L. ear	10/90 mins.	22	50	21.6.44
3.7" A.A., Pos: 4 L. ear	11/8 mins.	20	55	29.5.44
Rifle from hip, L. ear	80/15 mins. 80/30 mins.	19 18	65 55	10.10.44 20.10.44
6" coast ( $\frac{1}{2}$ charge), behind facing sideways, R. ear	6/5 mins.	14	30	20.6.44
4" Q.F. Naval, outside turret, L. ear	6/2 mins.	10	35	13.7.44
Vickers M.G., opposite 2, facing sideways, L. ear	60/10 mins. in bursts of 15	8	30	12.10.44
9 mm. submachine gun	30/10 mins. in short bursts	7	20	18.10.44
Rifle firing from shoulder	10/2 mins.	6	25	26.10.44
25 Pr. (17, ch. 1; 3 ch. 3), Pos. 6, L. ear	20/75 mins.	5	15	28.6.44
Bren gun in small yard, partly roofed, next to firer L. ear	28/8 mins. singly 125/1 mins. in 5 bursts	5 1	20 15	2.11.44 26.10.44
Owen gun, R. ear	250/10 mins. in short bursts	1	10	10.10.44
Vickers Pos. 1	120/20 mins. in burst of 15	1	5	12.10.44
Bren gun as above L. ear	28 in one burst	1	5	2.11.44

## Temporary Deafness due to Gunfire

susceptibility with repeated exposures may have contributed to these results, and for this reason the dates of each exposure are set out in the table. The question of decrease in susceptibility is discussed in a later paper (Ref 1)

2g Some of these figures do not give a true impression of the damaging effect of some of the guns, because there are gun positions likely to be more injurious than those occupied by this subject. However, as pointed out above, after the severe effects following exposure to the 17 Pr and the 18 Pr in the concrete emplacements had been produced it was felt to be unwise to repeat such exposures. Thus with the short 25 Pr. the position least likely to affect hearing was occupied. Four groups of two rounds were fired with intervals between each group of 18, 15 and 23 minutes. The peak loss in Db at 4096 c p s after each group was 20, 25, 30 and 40 respectively. After 50 more minutes position 4 was occupied, after which, the peak loss at 4096 c p s was 50 Db but this position caused so much pain that continuation of the exposure after two rounds was not practicable.

### 7. Blast Pressure Measurements

#### (a) TABULATION OF BLAST PRESSURES OF TYPICAL GUNS AND MORTARS

1a Figures for the maximum positive pressures, taken at the ear position of the subject, are presented in the following table, each figure representing a single measurement. The positions occupied are set out in figures 5, 8, 9 and 10.

#### (b) BLAST PRESSURE PHOTOGRAPHS

1b Photographs of the oscillograph tracings of the blast pressure curves are reproduced for the short 25 Pr, (figure 6), 18 Pr in concrete gun emplacement (figure 7), 3 inch Short mortar (figure 8), 3 inch Mortar (figure 9), 2 inch Mortar (figure 10) and the rifle (figure 11).

2b A feature of the pressure curves of the large guns and the mortars is the presence of several pressure peaks in the record. The initial peak is not usually the greatest. This is characteristic in general of flashing propellants and would be enhanced when normal charge is fired from a shortened standard gun as occurs with the Short 25 Pr and the Short 3 inch Mortar. The presence of several peaks is particularly marked in the records obtained when the mortars were fired. It would appear from our observations that the closer to the muzzle the gauge is placed, the greater is the number of peaks. Further away the pressure time curve of the blast wave becomes simpler in form. The two distinct phases seen in the mortar records are due possibly to incomplete detonation within the barrel of the weapon, a considerable secondary



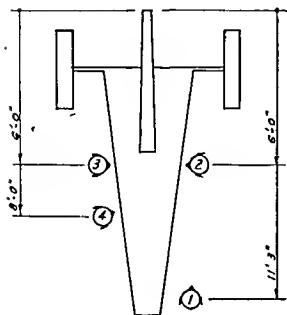
# N. E. Murray and G. Reid

## TABLE 2

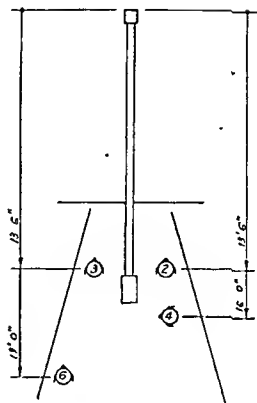
BLAST PRESSURES AT EAR POSITIONS AROUND GUNS

Gun	Position	Ear	Subject facing :	Maximum positive Blast Pressure (lbs/sq. inch)			
25 Pr. short (charge 3)	2	Right	Sideways	6.0	7.5	6.7	
	4	Left	Sideways	3.8	6.7	4.9	
	1	Right	Sideways	3.3	2.6		
	2	Left	Forwards	5.7	6.9		
	2	Right	Forwards	7.6			
3 inch mortar short (Bombs Mk. 3, 95 gr. ballistite and 12 sec. charges each 115 gr. cordite W.M.107)	1	Right	Forwards	7.0	5.7		
	2	Left	Forwards	7.8	8.4	7.5	7.3
	3	Left	Sideways	5.7			
	4	Left	Sideways	5.0			
3 inch mortar long (Amm. as above)	1	Right	Forwards	3.5	2.8		
	2	Left	Forwards	4.7	3.2		
	3	Left	Sideways	3.5			
	4	Left	Sideways	1.3			
17 Pr. T.A. gun with muzzle brake (A.P. Shot A.C. Service Charge)	2	Right	Sideways	6.9	7.9		
	4	Right	Sideways	7.4			
	6	Left	Sideways	6.8			
18 Pr. in concrete emplacement as coast gun  (Car. Q.F. 18 Pr. H.E. plugged)	To R. of 2	Right	Forwards	6.9	7.0	7.0	
	1	Left	Forwards	3.8			
		Right	Forwards	4.6			
	Amm. No.	Right	Forwards	3.8			
	Behind 1	Right (close to wall)	Forwards	4.7			
25 Pr. Mk. 2	2	Right	Sideways	(Charge 3) 2.7	3.4	(Super Ch.) 2.6	3.4
	2	Left	Sideways	1.6		1.2	
	2	Right	Forwards	2.1		2.4	
	2	Left	Forwards	2.8		2.1	
	1	Right	Forwards	1.1	1.3	0.9	0.8
	4	Left	Sideways	2.3	2.1	2.3	1.6
2 inch mortar Bombs M.E. Mk. 1 55 gr. Ballistite blue cart. paper	1	Right	Forwards	1.3	1.5	1.6	
	to R. of 1	Left	Forwards	1.8	2.0		
Rifle	Hip	Right	—	0.3	0.25	0.21	0.15
	"	Left	—	0.18	0.25	0.25	
	Shoulder	Left	—	0.15	0.21	0.15	
	"	Right	—	0.21	0.25	0.15	

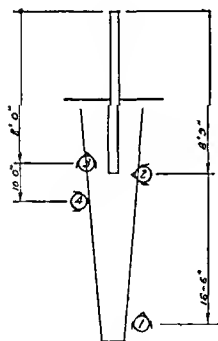
# Temporary Deafness due to Gunfire



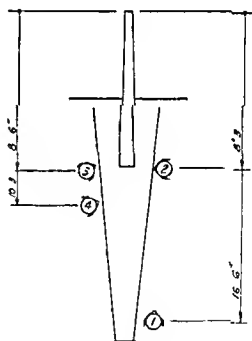
25 PDR SHORT



17 PDR T/A



18 PDR MK IV  
IN CONCRETE EMPLACEMENT



25 PDR MK II

## GUN POSITIONS

FIG 5

flash taking place outside. It is interesting with reference to these observations that the relatively simple curve shown for the rifle is replaced by a record showing a rapid series of positive and negative waves when the gauge is placed within a few inches in front of and to the side of the muzzle.

3b. In the 18 Pr. record there is a late secondary peak, possibly attributable to reflection from the roof or wall of the emplacement. The investigation of blast waves from guns in relatively enclosed spaces required further study. It is clear that the 18 Pr. gun when used as a coast gun in its emplacement with roof, rear and side walls, is much more detrimental to hearing than when used in the open as a field gun.

## 8. Relation of Blast Pressure Measurements to Aural Effects

### (a) FEATURES OF BLAST WAVE LIKELY TO AFFECT THE AMOUNT OF AURAL DAMAGE

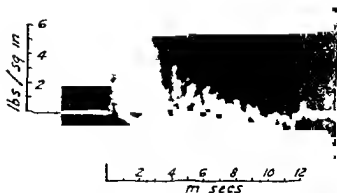
1a. When we attempt to find features of the blast wave which are most important in relation to hearing loss caused, we may consider the following :—

- (a) Maximum positive blast pressure.
- (b) Maximum positive impulse, i.e., the integration of the blast pressure time curve over the positive impulse.
- (c) Number of peaks in blast wave of harmful magnitude.
- (d) Time between peaks in blast wave curves.
- (e) Frequencies involved and their relative magnitude.

2a. From American data, which we have, it appears that the maximum energy is found in the region of 100 c.p.s. If we consider that the effect on hearing from a blast wave is similar to that from noise or loud tones we would expect the hearing loss to be mainly in the lower frequencies at about 128-256 cycles (ref. 17). This would be modified by the fact that higher frequencies are more effective in producing hearing loss than lower frequencies. An examination of our results of hearing loss in figure 1 and table 5 appendix showed that peak hearing loss most commonly occurred in octave 2048-4096 or 4096-8192. Also types of audiogram were more consistent from gun to gun on the one person than from person to person on the one gun. Detailed analysis of the frequency spectrum from gun blast was not considered useful for our purpose of relating blast pressure measurement to hearing loss. There are considerable physical differences between loud noise and blast waves of the order we are interested in here. The loud noise is only approximately .001 lb./square inch maximum pressure. Also blast waves are shock fronted.

3a. Effects from (c) and (d) are inter-related. When it was observed from our hearing loss diagrams that bursts of gun fire were

No 2 position  
Right Ear,  
Facing sideways



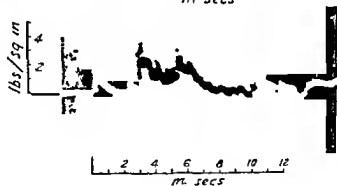
No 2 Position  
Right Ear  
Facing forward



No 2 Position  
Left Ear  
Facing forward



No 4 Position  
Left Ear  
Facing sideways



No 1 Position  
Right Ear  
Facing forward.

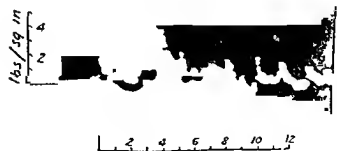
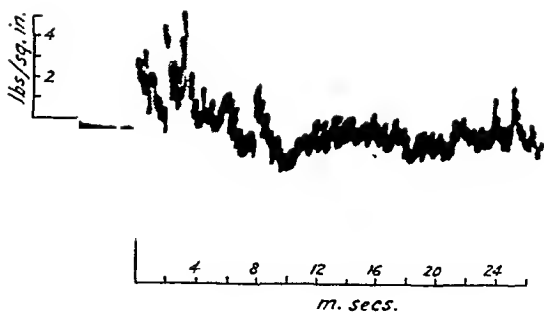
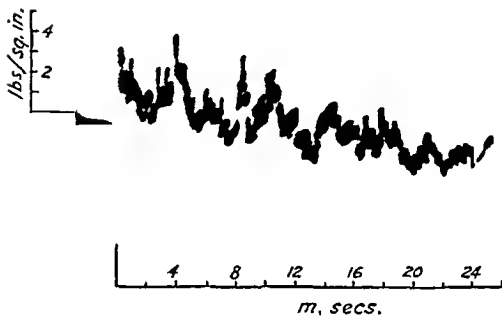


FIG 6  
25 Pdr short gun Grade III propellant charge

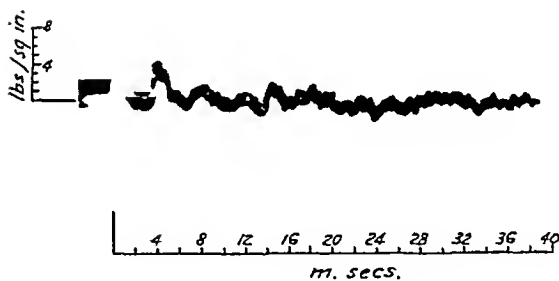
Beside No. 2  
Right Ear.  
Facing forward.



Ammunition No  
Right Ear.  
Facing forward.



Position No. 1  
Right Ear.  
Facing forward.



Behind 1.  
Immediately in front of rear  
wall.  
Right Ear.  
Facing forward.

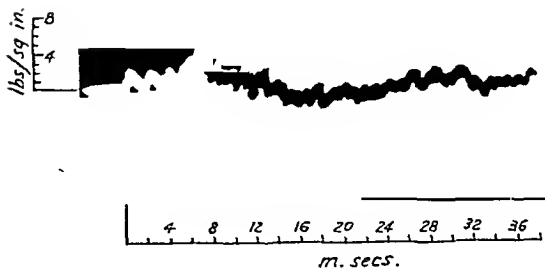
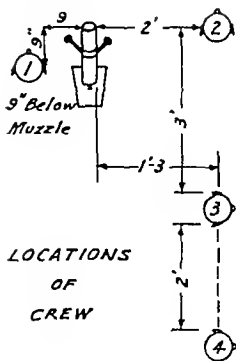


FIG 7.  
18 Pdr. gun in concrete emplacement.

No 1 Position  
Left Ear



No 1 Position  
Right Ear

No 3 Position  
Left Ear

No 4 Position  
Right Ear

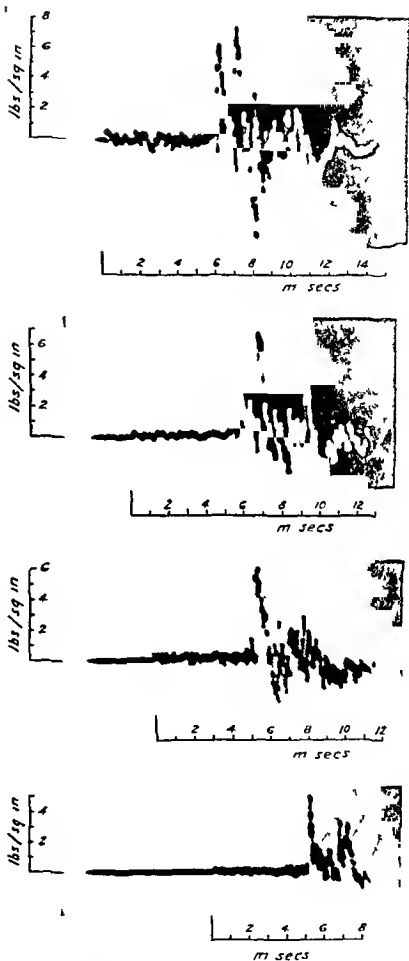
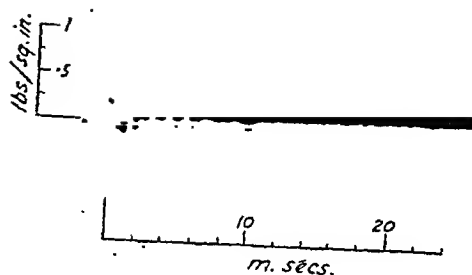


FIG 8  
3 in short mortar

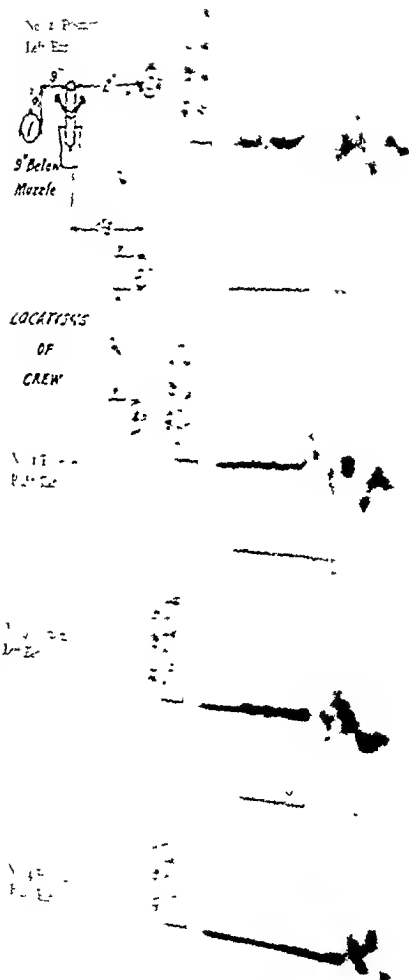
Left Ear.  
Firing from hip.



Left Ear.  
Firing from shoulder.



FIG. II.  
Rifle. 303 short Lee-Enfield.



## nfire

Paragraph 5a, page  
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the curve the time  
than that between  
in fact, all of them  
aural reflex. The  
major importance

is considered as of  
is interested in the  
mass, where it may  
for a light damped  
of following rapid  
expected to have a  
the impulse. The  
lead from the blast

Paragraphs 1a-4a, the  
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wave photographs.

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between the two  
index, were marked  
persons exposed  
in practice shoots  
posture regarding  
unavoidable.  
for the hearing  
dent exposures,  
es. In a series  
effect of number  
giving response  
average hearing  
t G.R. was of  
use in average  
page 114  
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## N. E. Murray and G. Reid

reasonable measure of the hearing loss to be expected in other sensitive subjects from these or other guns, from an exposure of approximately ten rounds. This number of rounds (10) is sufficient to even out large individual differences in resultant hearing loss likely to occur if comparisons are made from exposure to single rounds.

*It is suggested therefore that the best subjective criterion for measurement of hearing loss from gunfire is the hearing loss caused by exposure to 10 rounds. This could be known as the "Ten Round Hearing Loss".*

Care should be taken that on guns, known from measurements of blast pressure as being able to rupture eardrums in the worst positions, experimental subjects are only exposed in the less severe positions where the pressure is less than 4 lbs. per square inch.

4b. The increase in hearing loss with number of exposures has been studied in a subsequent paper (ref. 1, Reid 1945), so that approximate figures can also be obtained for the exposure to a different number of rounds.

TABLE 3  
HEARING LOSS FROM VARIOUS BLAST PRESSURES FOR A SUBJECT OF AVERAGE SENSITIVITY (G.R.)

Gun	Rounds	Loss Db. Average—Peak		Mean Peak Blast Pressure at Position occupied Lbs. per sq. in.
17 Pr. T.A. with muzzle brake	7*	49	85	7
18 Pr. in emplacement	20*	42	75	4.5
Short 25 Pr. (Pos. 1)	8*	17	45	3
25 Pr. Mk. 2	20*	5	15	1.8

\* This subject is approximately constant for hearing losses from exposures between 7 and 20 rounds (see 8b.3).

5b. From the above curves and from blast measurements taken of the worst positions of the Short 25 Pr. we would expect this gun in the worst position to cause particularly severe hearing losses although no subjects were actually exposed in these positions. We have no records of the loss of hearing of the 6 Pr. T.A. gun when fired. Blast pressures, however, were measured at the right ear of No. 2 and were for three readings 3.1, 3.4, and 3.3 lbs. per square inch respectively. Considerable hearing losses, are therefore, to be expected from this weapon.

6b. While table 3 and figure 12 have been drawn for a number of rounds, so as to get an approximate equivalent exposure, it is to be noted that severe hearing loss can occur from a single round from the higher pressures; thus N.E.M. suffered an average hearing loss of 38 Db. with a peak of 75 Db. from a single round of a 3 inch Short Mortar, (figure 3a, page 105).

# Temporary Deafness due to Gunfire

## (c.) "OTOLOGICALLY SAFE" LIMITS

1c. (a) *To prevent Deafness.* It has been stated in the past, that in order to prevent loss of hearing peak blast pressures should not exceed 2.5 pounds per square inch, and when the ear is plugged with dry cotton wool this limit is 7 pounds per square inch. Our results show that lower

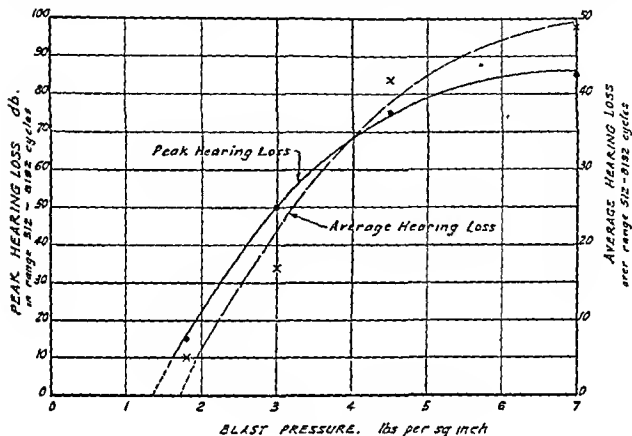


FIG 12

## BLAST PRESSURES v HEARING LOSS

### SUBJECT OF AVERAGE SENSITIVITY.

### EFFECT OF TEN ROUNDS AT SHORT INTERVALS

#### ("Ten Round Hearing Loss")

pressures than these will deafen, even though no discomfort be experienced. For example, the rifle which produces a peak pressure about one quarter of a pound caused loss of hearing in several subjects, firing from 80 to several hundred rounds. Cotton wool did not protect subjects exposed to pressures of the order of 4-7 pounds per square inch. (See section 10, page 116.)

2c. (b) *To Prevent Rupture of the Eardrums.* The work of

Zuckerman *et al.* at the time of the air raids on Great Britain indicated that peak blast pressures of the order of 15 to 50 lbs. per square inch will cause rupture of 50 per cent. of human eardrums. Some instances are also recorded there of drum rupture from blast pressures from bombs estimated to be as low as 2-4 lbs. per square inch. It is known, however, both from evidence in the literature and from conversations with artillery officers, that ruptured eardrums occur in gun crew members (exposed probably to blast pressures of the order of 6-8 lbs.). It is important, therefore, to record rupture of the tympanic membrane when the pressure was fairly accurately known—that is, 6-8 lbs. per square inch at position 1 of the Short 3 inch mortar. (See section 6d, page 104.)

### 9. Classification of Weapons in Respect to Aural Effects

1. The relationship between peak pressure in hearing loss makes it possible to tabulate the various guns in the following order with reference to need for protection of hearing.

(a) *Peak Pressures of 4-8 lbs. per square inch. Protection imperative:—*  
to prevent rapid hearing loss, and ruptured ear drums in some subjects.

Short 3 inch Mortar.

Short 25 Pr.

17 Pr. T.A. gun with muzzle brake.

18 Pr. in concrete emplacement.

3 inch Long Mortar.

(b) *Peak pressures of  $1\frac{1}{2}$ -4 lbs. per square inch. Protection essential:—*  
to prevent hearing loss.

6 Pr. T.A. gun.

3.7 inch A.A. gun.

25 Pr. Mk. 2.

2 inch Mortar.

(c) *Peak pressure less than  $1\frac{1}{2}$  lbs. per square inch. Need for protection varies with circumstances.*

*Protection essential:—*

Bofors, 2 Pr. guns, and small arms, at proof ranges.

*Protection desirable.*

Bofors, 2 Pr. guns.

*Protection doubtful.*

Inside gun turrets.

### 10. Means of Protection from Gun Blast

1. In no case, when one ear was exposed and the other ear protected by the Acoustic Research Laboratory earplug (ref. 24) known in the

# Temporary Deafness due to Gunfire

Army as Protector Eardrum Aust. Mk. 1, was deafness-detected in the protected ear. In order to test the protection given by these plugs in as severe an exposure as may be expected in action, the following experiment was made. The 18 Pr. in a concrete emplacement was used, because it is known to cause in these circumstances, very high blast pressures of the order from 4-7 lbs. per square inch, and it was possible to be present when several hundred rounds were fired from this gun. Six ears of four subjects, protected by cotton wool and seven ears of four subjects protected by the Protector were examined before and after firing. The results are set out in the following table:—

TABLE 4  
EXPOSURE TO BLAST PRESSURES OF 4.7 LBS PER SQUARE INCH  
EFFECT OF COTTON WOOL AND PROTECTOR EARDRUM AUST MK 1

Subject	Position		No of Rounds	Protection	Hearing Loss		Remarks
					Avg.	Max	
R G	Left	2 & 3	160	Cottonwool	nil	nil	See fig 1 L page 100
	Right	2 & 3	160	"	26	52	
G R Y	Right	Amm No	130	"	7	20	
T R E.	Right	Vari-ous	130	"	nil	nil	Complained of pain
	Left	"	130	"	"	"	" "
L B	Right	1	200	"	35	50	See fig. 1 M page 100
G R	Right	Vari-ous	250	Protector Eardrum Aust Mk 1	nil	nil	
E P S	Left	"	250	"	"	"	
	Right	1	220	"	"	"	
N E M	Left	1	220	"	"	"	
	Right	1	80	"	"	"	
R B R	Left		80	"	"	"	
	Right	2 & 3	96	"	"	"	

2. That cotton wool is an unreliable form of ear protection has long been recognized (Passe 1940, Guild 1941 and Taylor 1944). It is illustrated here by the audiograms of R.G. and L.B. in figures 1L and 1M, page 100. On the other hand subject G.R., protected by Protector Eardrum Aust Mk. 1 suffered no discomfort or loss of hearing after exposure to 250 rounds although 20 had caused considerable loss in the unprotected ear. (See figure 1J., page 100) The only effect noticed with the plugs, was ringing, which occurred rarely and lasted never more than a few seconds after each shot.

3. In these experiments the cotton wool was inserted by the wearers and appeared well inserted. They were experienced gunners and were accustomed to the use of cotton wool.

4. It is clear from the above remarks, as well as from other evidence extending back to the first world war, that cotton wool is insufficient ear protection, and that artillery personnel require adequate protection such as is provided by Protector Eardrum Aust. Mk. 1 in order to prevent hearing loss.

5. To what extent infantrymen firing rifles or sub-machine guns require protection cannot at present be stated. This study shows that deafness commonly follows small arms fire; but the answer to the problems (that is, protect the ears) is not so simple as with large guns, except in proof ranges. This is because the infantryman requires good threshold hearing, not only when he is on sentry duty after a day's action but during the whole period he is on patrol using his weapons. The question of how seriously the infantryman is deafened by small arms requires further exploration in the field.

#### 11. Significance of Deafness following Gunfire

1. The figures given and the graphs drawn represent threshold hearing losses. Thus a threshold loss of 30 decibels at, say, a frequency of 4096 c.p.s. means that a tone of that frequency which is *just* heard by a normal ear must be raised in intensity 30 Db. in order to be just heard by a deaf ear, that is, its energy value must be increased 1,000 times.

2. This does not mean that a tone of greater intensity (say 50 Db. above threshold) must be raised by a similar amount, that is 30 Db., in order to sound equally loud to the ear with a loss of 30 Db. at threshold. Actually it is characteristic of the deafness due to noise or gunfire that the loss of perceived loudness is not constant but is variable in the sense that it diminishes rapidly as the intensity of sound is increased. Consider, for example, a normal and a deaf ear differing in acuity at threshold by a given number of decibels. With sounds at the level of ordinary speech (60-70 Db.) the difference in the sensation of loudness between the two ears may be considerably reduced from the original difference at threshold intensity, and reduced even more so at the level of the noise in planes and tanks. The extent to which this occurs will depend on the size of the threshold loss.

3. The deafness produced by gunfire may be, therefore, of importance in :—

(a) affecting the ability to hear sounds at threshold level,

or

(b) affecting the ability to hear speech at various levels of intensity.

As pointed out above, the first of these effects is much more obvious than the second and it must be added that in everyday civil life threshold

## Temporary Deafness due to Gunfire

hearing is not usually of great importance. This should not be taken to belittle the importance of a threshold loss due to gunfire because in conditions of quiet, when an enemy may betray his presence by the slightest noise, threshold hearing acuity, at once becomes of the greatest importance. Moreover, many of the sounds which it is important to detect may contain a lot of high frequency components, that is, the rustle of leaves. It is for this reason that the importance of protecting hearing should be impressed on men exposed to gun and mortar fire. With many of the hearing losses recorded in these experiments the individuals would be impaired as sentries for several days. Where the men were again exposed before recovery the deafness would tend to become incremental and ultimately very great. There is also much evidence, not presented here to indicate that deafness ultimately becomes permanent, especially where exposure again occurs without complete recovery.

4 One other point requires emphasis. Usually one ear is more affected than the other. This means that not only will a subject have a threshold hearing loss but his localization of faintly audible sounds may be seriously impaired. The importance of this to a sentry is too obvious to require further elaboration.

5 So far as the ability to understand speech is concerned, much of the hearing loss particularly when the effects of gunfire were slight, lies outside the range which is of chief importance for the hearing of speech. When the exposure is more severe as in figures 1, C, D, J, M, R, T, Y, pages 99, 100 and 101, the speech range is involved. The maximum losses in these figures for the frequencies 512, 1024, 2048, and 4096 were respectively 15 Db, 35 Db, 70 Db, and 85 Db. Subject G R found considerable difficulty in hearing ordinary conversation in his right ear after the experiment of figure 1C, page 99, and subject F J B after the experiment of figure 2a, page 103, was deaf to all but loudly shouted conversation.

6 How then does the way in which loudness is recruited as described above affect the hearing of speech in deafness of the type under consideration? A rapid decrease in the difference between the loudnesses perceived by a normal and a deaf ear as the intensity of the source is raised does not mean that there will be a corresponding reduction in the difference between the articulation scores for the two ears at various intensity levels. (Steinberg and Gardner 1937, 1940) This is largely because some of the speech sounds, that is, "th" are faint and remain below the threshold of the deaf ear. Davis *et al* (ref 17b) investigated the articulation efficiency of subjects during the temporary deafness after exposure to noise and found in subjects with hearing losses comparable to the worst of our own, moderately large articulation losses at the 40 and 70 Db level, but because of the wide scatter of the points no

quantitative relation between hearing loss and articulation loss could be established. Articulation loss at the 100 Db. level was never severe.

7. Practically, the effect on hearing of conversation at the ordinary speech level of 60-70 Db. may be summarized as follows. When loss is as severe as obtained after firing the 17 Pr. there will be considerable impairment of hearing of speech whereas with mild losses (as in figures 1. G. H. N, and O, pages 99 and 100), the impairment of hearing at ordinary speech levels will be slight and the subject not appear obviously deaf to his fellows.

8. These facts have a bearing on the question of protection and the way orders are given to gun crews. If the drill is such that orders reach the members of a gun crew at say 60 Db., then if plugs are worn, naturally there will be a difficulty in hearing them. On the other hand, without plugs, there will be a loss of hearing due to the gunblast which, at that level of intensity, will of itself impair the hearing of orders. If the wearing of plugs is part of the normal gun drill, then it should be possible to transmit orders so that they will be properly heard, despite the overall 30 Db. loss which a good plug gives. This loss, moreover, will remain constant over a period of action. The intensity level at which orders should be given and the articulation loss caused by plugs or gunfire deafness at this and other intensities, particularly in battle noise requires further exploration in the field.

9. To what extent, apart from its effect on hearing, gunblast impairs efficiency, is undetermined. It is undoubtedly true, however, that when the ears are properly protected, the gunner's attention and activity are no longer directed towards protecting his ears—by raising his hands, by tilting his head or by other tricks. For these reasons our impression is that the wearing of comfortable plugs not only prevents hearing loss but improves the general efficiency of the gunner. To what extent, also, the "tenseness" associated with waiting for the gun to fire, contributes to fatigue is unknown. It may become less with experience. At all events, the most unpleasant features of gunfire is removed when the ears are protected and subjects lose most of that tenseness and apprehension.

10. The facts in this discussion emphasize the importance of impressing upon gun crews during their training that it is not effeminate to wear ear plugs, but that the care of their ears is as important as the care of their weapons.

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APPENDIX—TABLE 5

Ear	Gun etc.	Pos.	Rds/time	Time after	Hearing loss in Db. at:—						
					512	1024	2048	4096	5793	8192	9749
G.R. (R)	17 Pr. T.A. with brake muzzle	2	7/4 m.	15 m.	15	25	40	85	85	75	70
C.T. (R)	"	3	9/7 m.	55 m.	-5	5	0	10	60	60	55
C.T. (L)	"	3	9/7 m.	55 m.	5	0	5	5	15	50	70
R.C. (R)	"	4	9/7 m.	45 m.	0	0	5	20	20	15	15
R.C. (L)	"	4	9/7 m.	45 m.	5	10	25	50	35	65	15
G.R. (L)	18 Pr. in concrete emplacement as coast gun	1	20/40 m.	15 m.	10	25	40	70	75	45	65
R.G. (R)†	"	2 & 3	160/5 hrs	15 m.	0	0	20	60	50	45	35
L.B. (R)	"	1	200/5 hrs	30 m.	10	35	40	50	—	20	35
G.R. (L)	25 Pr. short	1	8/60 m.	10 m.	0	0	10	35	45	40	50
		1 & 4	8 & 2/110 m.	10 m.	0	5	10	45	55	50	50
K.K. (R)	"	1	16/4 hrs	15 m.	-5	10	5	0*	—	10*	—
K.K. (L)	"	1	16/4 hrs	15 m.	0	5	0	10*	—	10*	—

\* Initial hearing 30 Db. or more below audiometer zero. † Ear plugged with cotton wool.

# Temporary Deafness due to Gunfire

Ear	Gun etc	Pos	Rds/time.	Time after	Hearing loss in Db. at				
					512	1024	2048	4096	5793
F J.B. (R)	Rifle from hip		350/5 hrs	15 m.	25*	45	25*	35*	25*+
F J.B. (L)	"		"	15 m.	20*	-10*	15*	30*	5*+
R.M. (R)	"		110/30 m.	15 m.	-5	5	10	45	15
R.M. (L)	"		"	15 m.	-10	-5	30	40	40
L.W. (R)	"	Firer Vicinity	100 } 90 m. 400 }	15 m.	-1	-10	-5	0	15*
L.W. (L)	"	Firer Vicinity	100 } 90 m 400 }	15 m.	-	-5	10	10*	NH.
G.R. (L)	"	(On right in corr. pos to firer)	80/30 m	10 m.	0	5	0	45	55
G.R. (L)	"	"	80/15 m.	15 m.	0	0	-5	35	65
E.P.S. (R)	3.7" A.A.	3	11/8 m	12 m.	5	0	20	45	65
G.R. (L)	"	4	11/8 m.	17 m.	0	5	10	40	55

\* Initial hearing 30 Db or more below zero of audiometer

TABLE 5 (CONTINUED)

Ear	Gun etc.	Pos.	Rds/time	Time after	512	Hearing loss in Db. at:—				8192	9747
						102.4	204.8	4096	5793		
B.R. (R)	9.2" B.L. (1ch.)	Amm. No Rammer	10/90 m.	40 m.	5	5	0	10	0	25	20
B.R. (L)	"	"	10/90 m.	40 m.	0	0	-5	0	5	20	0
H.F. (R)	"	Layer for elevation	10/90 m.	25 m.	0	5	5	0	0	0	0
H.F. (L)	"	(port open)	10/90 m.	25 m.	-5	5	5	5	0	0	0
E.P.S. (L)	"	Outside turret	10/90 m.	15 m.	0	10	5	25	60	55	—
G.R. (R)	"	"	10/90 m.	10 m.	0	5	20	50	35	35	55
R.M. (R)	Rifle in Enfield support for accuracy calibration in shed	On right in corr. pos. to firer	15/15 m.	15 m.	-5	0	15	45	40	40	40
S.S.R. (R)			32/30 m.	15 m.	0	35	35	0	35	35	20
S.S.R. (L)			32/30 m.	15 m.	-5	-5	10	10	5	5	25
R.H.L. (L)	4" Q.F. Naval	Layer (port open)	6 1/2 m.	10 m.	-5	5	0	5	—	-5	-5

# Temporary Deafness due to Gunfire

Ear	Gun etc.	Pos	Rds/time	Time after	Hearing loss in Db at —				
					512	1024	2048	4096	5793
GR (L)	4" Q T Naval (contd)	Outside turret	6/2 m	20 m	0	0	5	20	30
CB (R)		Layer (port open)	6/2 m	15 m	—	0	0	0	0
LPS (R)	6" coast (1/4 charge)	Setter in Pit	6/5 m	15 m	0	5	0	10	20
GR (R)		1 (side on)	6/5 m	20 m	5	5	20	20	15
CLC (R)		Amm No	6/5 m	25 m	0	0	-5	0	10
JK (R)		RBL in Pit	6/5 m	10 m	0	0	0	-5	-5
JK (L)		RBL in Pit	6/5 m	10 m	0	0	0	-5	0
MRF (R)	Vickers MG	1 or 2 or in vicinity	1000 rds 4 hrs (bursts of 15)	15 m	0	0	20	20*	15*
MRF (L)				15 m	10	0	5	5*	5*

\* Initial hearing 30 Db or more below audiometer zero

TABLE 5 (CONTINUED)

Ear	Gun etc.	Pos.	Rds/time	Time after	512	1024	Hearing loss in Db. at:—			8192	9747
							2048	4096	5793		
Mc.S. (R)	Vickers M.G. (contd.)	1 or 2 or in vicinity	1000 rds. 4 hrs. (bursts of 15)	25 m.	5	0	0	15*	—	5*	—
Mc.S. (L)	"	"	"	25 m.	—	10	5	15	—	-5*	—
G.R. (L)	"	1	120/20 m. (bursts of 15)	15 m.	0	0	0	0	5	5	0
G.R. (L)	"	Opp. 2 in corr. pos.	60/10 m. (bursts of 15)	15 m.	0	0	0	20	15	30	15
G.R. (L)	"	"	"	"	"	"	"	"	"	"	"
G.R. (L)	9 mm special sub- machine gun	Firer	30/2 m. (short bursts)	10 m.	0	0	0	20	10	20	50
S.M.W. (R)	"	"	100 in short bursts	10 m.	0	0	5	10	—	-5	5
S.M.W. (L)	"	"	"	10 m.	0	0	0	5	—	5	0
C.H. (R)	"	"	30/2 m.	15 m.	0	-5	0	0	0	5	—
C.H. (L)	"	"	"	15 m.	0	0	0	0	0	5	—
G.R. (L)	Rifle from shoulder	Firer	10/1 m.	10 m.	0	0	0	10	20	25	35

\* Initial hearing 30 Db. or more below audiometer zero.

# Temporary Deafness due to Gunfire

Ear	Gun etc.	Pos.	Rds/time	Time after	Hearing loss in Db. at:—					8192	9747
					512	1024	2048	4096	5793		
A L (R)	Bren M G.	firer	125 in 5 bursts	10 m.	-10	-15	0*	-5*	0*	N.H.*	—
A.L. (L)	yard partly roofed	"	"	10 m.	0	5	0	-5*	0*	N.H.*	—
D.A G. (L)		to L. of firer	28 in a burst	10 m.	0	0	0	0	0	-5	0
D.A G. (L)	"		28 single shots	10 m.	5	10	70	65	60	50	50
G.R. (L)	"	to R. of firer	28 in a burst	10 m.	0	0	0	0	5	0	0
G.R. (L)	"		125 in 5 bursts	10 m.	0	0	0	5	15	0	5
G.R. (L)	"	"	28 singly	10 m.	0	0	0	10	15	20	5
A.M L. (R)	"	to L. of firer	28 in a burst	10 m.	0	-5	0	5	20	-5	0
A.M L. (R)	"		28 singly	10 m.	5	10	10	65	55	50	35
J.M. (R)	"	"	28 singly	5 m.	-5	-5	-5	-10	0	0	10
G R (L)	25 Pr Mk 2	6	20/75 m. 17: Ch. 1 3: Ch 3	20 m.	-5	0	0	15	15	10	20
T N B (R)	"	2	( 18/90 m. 15: Ch 1 3: Ch 3)	45 m.	5	10	15	10	5	10*+	5*+

\* Initial hearing 30 Db or more below audiometer zero

TABLE 5 (CONTINUED)

Ear	Gun etc.	Pos.	Rds/time	Time after	512	1024	2048	Hearing loss in Db. at :— 4096	5793	8192	9747
T N B (L)	25 Pr Mk. 2 (contd)	2	18/90 m. 15: Ch. 1 3: Ch. 3	45 m.	10	5	20	10	10*+	0*+	N.H.
E.V.M (R)	"	2	25/90 m.	60 m.	0	0	5	10*	10	15	25
E.V.M (L)	"	2	25/90 m.	60 m.	0	0	0	10	0	10	0
R.A.C (R)	"	4	12/90 m.	55 m.	0	0	10	5	15	10	—
R.A.C (L)	"	4	12/90 m.	55 m.	10	5	10	5	5	5	5*
F.L. (R)	"	5	28/75 m.	65 m.	0	0	0	5	5*	5*	0*
F.L. (L)	"	5	28/75 m.	65 m.	5	5	-5	0	—	-5	0
J T (R)	"	2	10/7 m. All ch. 3	30 m.	5	15	5	0	5	5	-5*
J.T. (L)	"	2	"	30 m.	5	10	10	5	—	0	5*
G.R. (L)	Owen, 9 mm.	Firer	250/10 m. (short bursts)	10 m.	0	0	0	5	10	0	15
E.P.S (L)	40 mm Bofors	2	19/	60 m.	0	0	0	0	10	-5	0

\* Initial hearing 30 Db or more below audiometer zero.

# Temporary Deafness due to Gunfire

Ear	Gun etc	Pos	Rds/time	Time after	Hearing loss in Db at				
					512	1024	2048	4096	8192
RAS (R)	Twin 6 Pr Coast	Layer for line	73/10 m	10 m	5	20	20	20	10
RAS (L)	"	"	73/10 m	10 m	10	10	5	5	5
EPS (L)	"	Amm No	200/30 m	15 m	0	0	0	0	0
HLJ (R)	"	5	50/6 m	20 m	0	5	0	5	10
HLJ (L)	"	5	50/6 m	20 m	5	5	0	0	—
KK (R)	2" Mortar	Firer	30/10 m	20 m	0	5	10	15*	—
KK (L)	"	"	"	20 m	0	0	5	25*	—
FOR (L)	"	to R of firer	"	30 m	5	25	40	45*	65+
BCE (R)	"	to L of firer	"	15 m	0	5	10	15	20
CLV (R)	"	Firer	9/30 m	15 m	5	-5	45	20*	40
CLV (L)	"	Firer	12/40 m	15 m	—	-5	35	20*	50

\* Initial hearing 30 Db or more below audiometer zero



TABLE 5 (CONTINUED)

Ear	Gun etc.	Pos.	Rds/time	Time after	512	1024	Hearing loss in Db. at:— 2048 4096 5793	8192	9747
L.S.P. (R)	3" long mortar	1	4/2 m.	10 m.	5	5	0 0 0	5	10
S.T.E. (R)	"	2	4/2 m.	5 m.	0	0	0 0*	0*	
S.T.E. (L)	"	2	4/2 m.	5 m.	0	0	0 0*	0*	
G.R. (L)	"	3	4/2 m.	15 m.	0	0	0 0 5	10	20
L.S.P. (L)	3" short mortar	3	3/3 m.	15 m.	—	0	10 20 30	25	25
N.E.M. (R)	"	1	1 m. 1 (80 m. later)	10 m.	15	20	30 75 70	50	70+
		1		10 m.	25	30	30 75 85	55	70+

\* Initial hearing loss 40 Db. or more below audiometer zero.

## CLINICAL RECORD

### HERPES ZOSTER OTICUS—(WITH OWN CASE NOTES)

By GEOFFREY MOREY (Lincoln)

HERPES ZOSTER OTICUS or Inflammation of the Geniculate Ganglion is a rare disease which was first described by Ramsay Hunt in America in 1907. Since his work on this condition there has been little of importance added and most modern text books treat the subject very inadequately.

It is generally agreed that this disease is caused by a filterable virus which gains entrance through the nasal or buccal mucous membranes, and sets up an acute hæmorrhagic inflammation of the sensory ganglia of the cranial nerves. More specifically, the changes consist of œdema and congestion with minute hæmorrhages and round celled infiltration followed by degeneration of the nerve cells and fibres in the posterior root ganglia, which are ultimately succeeded by regenerative changes in the peripheral nerves.

Herpes Zoster Oticus is characterized by extreme pain and by the formation of vesicles on the skin or mucous membrane in the zona of the ganglia involved. The geniculate ganglion of the VIIth nerve is primarily affected, but owing to the complex anastomosis of nerves in this region, neighbouring ganglia may also be involved, as in the case of my own illness, about to be described.

There may be certain predisposing factors such as trauma, chilling, malaise or the presence of septic foci (e.g. tonsils or sinuses), but it is equally likely that it may start insidiously for no apparent reason at all.

Hunt classified the disease into four sections in accordance with the number of ganglia involved.

1 *Herpes Zoster Oticus*, where the geniculate ganglion is solely affected. It is characterized by herpetic eruptions on the auricle and in the auditory meatus.

2 *Herpes Zoster with Facial Paralysis*. In this stage the lesion is more extensive. In addition to the usual herpetic condition motor fibres of the facial nerve are affected by the pressure of the effusion, causing rapid development of paralysis. As the chorda tympani is given off from the facial nerve in the Fallopiian canal it is usually involved also and the sensation of taste in the anterior two thirds of the tongue is distorted or lost. Vesicles may form upon the tongue itself.

3 *Herpes Zoster Oticus with Facial Paralysis and Deafness*. If severe enough, the inflammation of the geniculate ganglion may spread rapidly to the neighbouring ganglia of the VIIIth, IXth and Xth nerves since none of these nerves possess a capsule. The Ganglion of Corti may thus be affected causing mild hypoacusis or even total deafness in that ear.

4 *Herpes Zoster Oticus with Facial Paralysis and Meniere's Syndrome*. This is the most severe and complex form of the disease for in the same way that the organ of Corti may be involved, so may the vestibular ganglion be

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affected, with consequent disturbance of equilibrium. (It is possible that the vestibular ganglion may be affected without any affection of the organ of Corti.) On the other hand, however, the petrosal or jugular ganglia may be attacked, causing herpes of the pharynx or larynx. (Dan Mackenzie in 1915, and V. E. Negus in 1943 have recorded cases of herpes laryngis, with recurrent laryngeal nerve paralysis.) Further inflammation may involve the 2nd and 3rd cervical roots with which the facial nerve is known to be intimately connected, causing "herpes occipitocollaris".

This illness may commence with malaise, headaches or temperature, or there may be a sudden onset with pain, which quickly overshadows everything else. The pain is usually so intense that it can be relieved only by morphia. It is often accompanied by nausea and vomiting. Usually it is referred to the middle ear or the mastoid, or both, and it is only some four or five days after the onset that the vesicles appear, though facial paralysis may precede or follow the eruption.

The diagnosis of Herpes Zoster Oticus should present no difficulty once the vesicles have appeared, but in the initial stages when temperature is present, together with severe pain in and over the mastoid process; when facial paralysis and a reddened inflamed tympanic membrane are evident, an unwary observer might be led into the belief that he was dealing with a case of mastoiditis where the drumhead had not ruptured. The diagnosis may be still more difficult if otitis media exists as a complication.

When the geniculate ganglion inflammation has also caused facial paralysis and vestibular irritation the diagnosis of suppurative labyrinthitis might be made.

*Prognosis.* Most authors seem to agree that the facial palsy recovers in a few weeks to a few months. Vertigo also rarely lasts longer than a few months, and usually clears in a matter of weeks. Auditory symptoms may disappear, but of all the symptoms presented, they are the most likely to remain permanent.

Paroxysms of pain may continue for many months and in old people especially may never entirely disappear. The disease is never fatal.

*Treatment.* There is no known drug that will shorten the disease, though some authors think that Vitamin B<sub>1</sub> Complex has some slight beneficial effect. Therefore, treatment can only be directed towards alleviating the symptoms, the chief of which is the severe pain. It has been suggested that slight temporary relief is obtained by the application of cocaine to the sphenopalatine ganglion—other observers state that the injection of Pituitrin sometimes gives relief.

Rest in bed, catharsis and suitable diet are essentials.

## Report of my own Illness

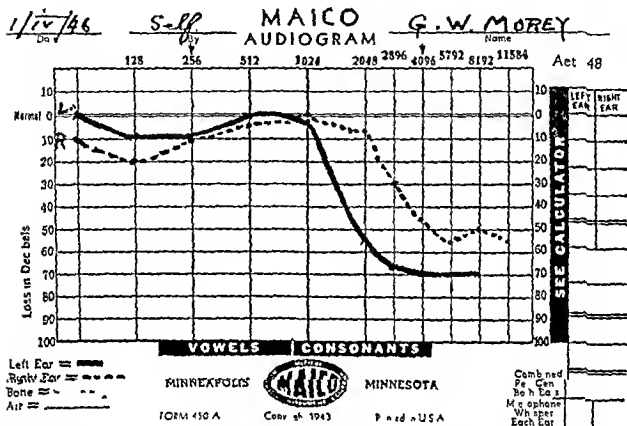
*1st Day.* Mild pain in the region of the base of tongue on left side. This suggested the presence of a fish bone.

*2nd Day.* Pain in throat increased and was now accompanied by a dull ache in the left ear. An examination by an aurist colleague revealed no abnormality except for a thickened red band behind the posterior pillar of the (empty) tonsillar fossa.

4th Day Pain now severe, especially in the ear Malaise Temp 101  
Another examination revealed nothing further except for a very slight pinkness of the tympanic membrane

5th Day Very intense pain, accompanied by extremely severe headache Temperature still 101 Slight deafness noticed in the left ear

6th and 7th Days Pain and headache increasing and causing prostration for which Morphine gr  $\frac{1}{2}$  was given This eased the pain considerably, but vomiting commenced soon afterwards and lasted for thirty six hours (This vomiting may of course have been due to the morphia, but vomiting is a recognized



Routine Audiogram made only eight days before the commencement of the Herpes Zoster to ascertain if there were any increase in the nerve deafness This nerve deafness is ascribed to a crash when flying in 1918 which caused unconsciousness for seven days

symptom of herpes zoster) A few crops of vesicles were now apparent and at this stage the diagnosis of herpes zoster oticus was made

These vesicles were situated on the auricle and within the auditory meatus—some were seen on the drumhead itself One crop was situated just below the tip of the mastoid extending downwards for about an inch There were also scattered vesicles over the left temple and one in the left eyebrow A few scattered vesicles were also found in the hairline just above the ear and later a vesicle was discovered in the pharynx near the base of the tongue on the left side

8th Day The tympanic membrane was very red and bulging posteriorly Myringotomy was performed but only a drop of mucoid material exuded through the incision This was cultured and grew *B. proteus* so that the courses of sulphathiazole and penicillin which had been started two days

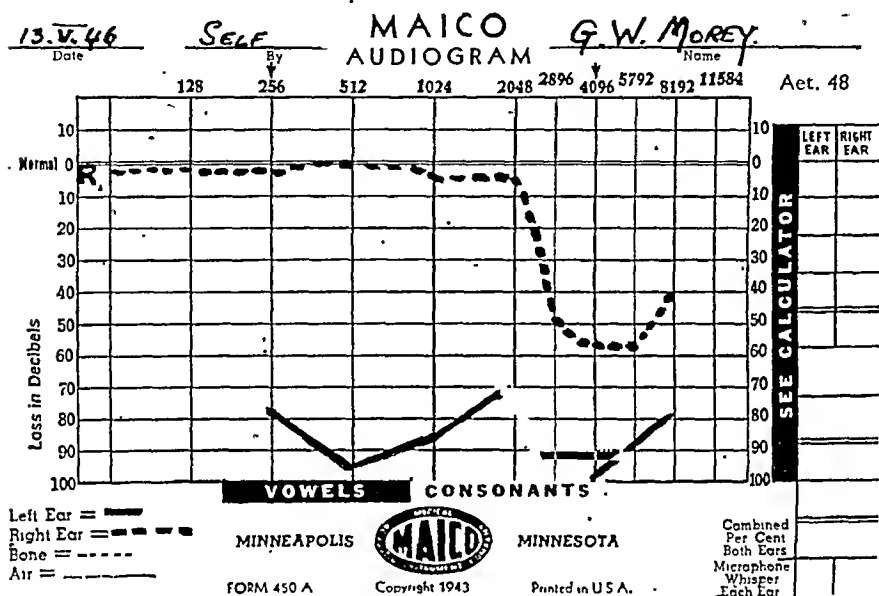
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earlier, were discontinued. There was considerable crusting of only those vesicles which were situated on the auricle or in the meatus.

Slight nystagmus and some vertigo were present.

9th Day. Overnight a complete VIIth nerve palsy developed, and the deafness had gradually increased in severity until I was unable to hear any sound with this ear. From crude testing it appeared that this deafness was of the "perceptive" type. (Further note on deafness later.)

The vertigo and nystagmus were marked, but caused no great inconvenience when lying still with eyes closed.



Audiogram made approximately a month after the onset of the Herpes Zoster. The hearing of the left ear is not accurately shown by the chart, since the frequency of 2048 seemed to be the only true frequency heard. The others were mostly octaves or double octaves of the original note. Thus, whatever hearing remains in this left ear would appear to be centred around 2048.

14th Day. Pain had now returned and was intense enough to prevent sleep even with drugs.

This pain consisted of two separate and distinct types. The "zoster" pain was paroxysmal and felt chiefly in the depths of the ear, but it also radiated to the temple and also down the border of the left sternomastoid muscle into the neck where it terminated in the pharynx.

The other pain is more difficult to describe, for it was essentially an acute hyperaesthesia over the whole superficial area supplied by the Vth nerve. A touch of the bed sheet or even of a strand of wool was sufficient to cause the most exquisite burning pain over the face and scalp and ear, which lasted for  $\frac{1}{2}$  to 1 minute. Brushing of the teeth had to be abandoned for a few days because of local pain.

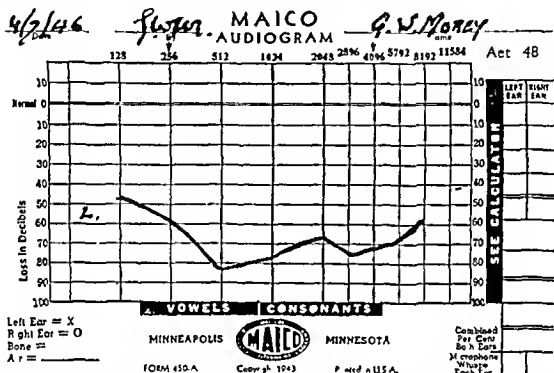
At about this time it was noticed that all food was unpalatable, and gave

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a sensation of "woolliness"—due to interference with the activity of the salivary glands There was also a definite perversion of taste, for some food now tasted quite bitter At times, certain food entirely lacking in salt tasted "coppery"

(It is probable that these gustatory symptoms were present just after the onset of the facial paralysis, but they were overshadowed by other symptoms and not noticed at the time)

30th Day The paroxysmal pain was still intense, but not frequent It was usually worse at night, and I myself wondered if some functional element



Very slight improvement in hearing is evident but is not sufficient to be appreciated There is still a good deal of confusion in making this audiogram because of octaves of the lower frequencies which are related to 2048

might be present because of this periodicity Later, during the paroxysms it was noticed that the ear became very dusky in colour and that it was much hotter than that of the other side

Hyperæsthesia was still sufficiently acute to prevent lying on that side but nevertheless considerably improved Vertigo still present, especially on movement of the head Gait still unsteady and walking in the street alone was impossible, as the labyrinth on the sound side was not sufficiently compensating

Facial paralysis began to improve about five days previously and each day there was some improvement in the facial muscles, though there is still inability to close the eye Drying of the cornea causes marked reflex blinking of the other eye and some loss of vision with considerable inconvenience Eating was slightly less difficult now and taste disorders have almost vanished

40th Day Vth nerve hyperæsthesia has diminished Facial paralysis has partially recovered, after a short course of Faradism The eye cannot yet be closed voluntarily Taste normal Deafness has not improved and

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is the most worrying symptom. Vertigo, except on sudden movement of the head, is absent but the gait is not yet entirely steady, there being an occasional tendency to "teeter" off to the right or left. With all volition possible, this cannot be controlled.

Paroxysms of pain continue and are sometimes very severe. They are less frequent.

*48th Day.* Slight hyperæsthesia still present—chiefly confined to auricle, but in the anti-helix there is an area about an inch in diameter which is anæsthetic or almost so. (The reason for this is obscure.) There is still inability to close the eye, though with the Faradic treatment the VIIth nerve paralysis is rapidly improving.

The deafness has not improved. Some unsteadiness in gait is still present. Paroxysms of pain continue and are sometimes severe.

On this day I was able to consult a London otologist. His tests and audiograms showed no divergence from my own. The prognosis for the recovery of hearing is assumed to be poor, partly because almost all perceptible sound appears to be related to one frequency (e.g. 512 and 1024 are heard as 2048).

A curious feature of this illness has been the absence of tinnitus. Only now, in the last week, has occasional tinnitus been present. It is slight.

The Eustachian tube has been quite free throughout and self inflation is quite easy.

There has been no involvement of the cornea.

As the facial paralysis improved it has been observed that certain loud noises, whether music or sounds in every day life, have caused a high pitched tinny rattling sensation in the deaf ear. This is assumed to be due to the partial recovery of the Stapedius muscle.

*90th Day of Illness.* Hyperæsthesia has disappeared. A large portion of the auricle around the concha is still almost completely anæsthetic. Facial paralysis is less obvious, but the left eye cannot be closed independently of the right, and whistling is not possible.

Deafness—no apparent change (Audiogram). Some diplacusis still. Vertigo is absent, and the gait is almost normal except when vision is reduced. For example, in the twilight or in the dark, the unsteadiness makes unaided walking impossible.

Tinnitus is now present almost constantly, but is only distressing occasionally.

Pain has gradually ceased and does not occur at all now.

### Note on Deafness

I was unable to make any audiometric tests until the thirtieth day of the illness.

With the sound ear adequately masked, it was then just possible to hear some tones in the affected ear by air conduction only. Nothing was heard by bone conduction.

As is usual in most severe cases of nerve deafness, the tones, when they did become audible, did so with a sudden sharpness and clarity, leaving little doubt

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about the exact point of audibility. Hearing was undoubtedly most acute for the frequency of 2048, where the loss amounted to 70 db.

For certain frequencies—e.g. 512, 1024,—some diplacusis was noticed.

Diplacusis—a most interesting phenomenon—can be most distressing, especially to those of us who have a love of music. At first it was noticed that the tone heard by the deaf ear was an octave, or two octaves above that heard by the sound ear. Later it was observed that in addition the note was sharp. Tests were then made to boost the hearing of the deaf ear with an electrical hearing aid, and to listen to music with it. The results were as expected. The musical work could be recognized, but there was so much distortion that listening was almost painful.

Audiometric tests done two weeks after the original, showed no change whatever.

The present position is that the good ear is still unable to compensate fully for the vestibular disturbance or for the deafness. The driving of a car is possible but is very unpleasant chiefly because of the loss of direction of sound. Up till now there has been no appreciable recovery of this loss.

Conversation in a quiet room with one good ear is not difficult but when the noise level is raised, as in a train or bus, or a crowd, words become quite indistinguishable.

Listening to music is no longer a pleasure. For many years I had considered myself a connoisseur of tone quality, but with only one ear tone quality is entirely lacking. It is as though a landscape were to become colourless.

In view of the poor prognosis any comments or advice that this paper might elicit would be sincerely welcomed.

### Anatomical Summary

Owing to the very complex anastomosis of nerves in the area of the geniculate ganglion any explanation must be somewhat involved.

1. Inflammation of the VIIIth nerve is by direct extension from the geniculate ganglion, and by the sensory nerve of Wrisberg. Moreover the VIIth and VIIIth nerves are enveloped in the same sheath and course together in the same osseous canal, where any expansion or swelling would be resisted and the effect of pressure increased.

2. Hunt wrote in 1909, 'The sensory system of the VIIth nerve passes to the tympanic cavity, mastoid and Eustachian tube by the petrosal nerves. In the case of the tympanic cavity Jacobsen's nerve (tympanic branch of the glossopharyngeal) is connected to the facial by the small superficial petrosal nerve, and by the great superficial petrosal nerve.'

The lesions in the posterior part of the auricle and in the auditory meatus are explained by the connections between the facial and Arnold's nerve (auricular branch of the vagus).

3. Through the greater and lesser superficial petrosal nerves and the vidian nerve, the facial makes contact with the otic and sphenopalatine ganglions, and from these the fibres of the second and third divisions of the Vth connect with the soft palate and the fauces.

4. The chorda tympani branch of the VIIth nerve is given off from the lower end of the Fallopiian canal and passing across the upper part of the



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tympanic membrane ultimately supplies the sensation of taste to the anterior two thirds of the tongue. Alterations of taste are thus explained and the fact that vesicles have been recorded on the tongue itself suggest a somatic sensory component in that nerve.

(Wakeley and Mulvany in 1939 pointed out that the taste impulses from the anterior two thirds of the tongue may be carried by the great superficial petrosal nerve *via* the otic ganglion, equally as well as by the chorda tympani.)

5. The hyperæsthesia in this case is presumed to have resulted from a spread of the inflammation to the whole Gasserian ganglion.

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(Founded in 1887 by MORELL MACKENZIE and NORRIS WOLFENDEN)

*March 1946*

## A NEW METHOD OF TESTING THE HEARING EFFICIENCY OF AVIATION CANDIDATES\*

By Air Commodore E D D DICKSON Wing Com J F SIMPSON Sq Leader  
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### Summary

The hearing test at present in use in the R A F is unsatisfactory for the selection of aircrew as it does not measure the type of hearing ability required for the efficient performance of flying duties

This report describes a series of experiments which have been carried out with a view to devising a suitable substitute for the present test

As a result of these experiments a new test is recommended which should prove free from the defects of the present method of testing. The new test measures the ability to recognize speech sounds which are transmitted through an electrical communication system and are masked by a noise similar to that encountered in Service aircraft

An additional test has been devised by means of which any deterioration in hearing acuity during service can be assessed. This test gives a rough estimate of hearing loss at four frequencies in the range 250-4000 c p s

A compact form of testing equipment has been designed for use in applying both those tests at Aviation Candidates Medical Boards

\* This research work has been carried out in the Acoustics Laboratory, Department of Otorhinolaryngology, Royal Air Force Central Medical Establishment



# Testing Hearing Efficiency of Aviation Candidates

flying duties who would in fact be quite capable of performing those duties. This must constitute the chief objection to the present method—that it does not test the kind of hearing ability which it is required to measure when assessing candidates' suitability for aircrew.

The other weaknesses of the present test lie in the lack of standardized testing conditions. The test is applied by a large number of medical officers at various centres. There are differences in the technique of the medical officers who give the test, involving differences in the quality and intensity of the whisper which is used. The listening conditions in the examining centres vary quite widely. Rooms of different sizes, shapes and materials are used and varying amounts of ambient noise may be present when the candidate is tested; in some centres there is always a high level of background noise, in others a reasonably low level, and in the majority the noise level fluctuates considerably throughout the day. Again, the speech material used for the test is not well controlled. In some cases, the medical officer has a small selection of words which he uses for every candidate. These words soon become known by the men who come up for medical examination and it is quite possible for a candidate to pass the examination if he can pick up only a very small fraction of the signal which is whispered to him since he is in the position of knowing what to expect. Other examiners use a large variety of words and thus make it impossible for the candidates to know what to expect. Again, there is no fixed policy as to the type of word to be used, nor as to what constitutes the passing of the test. In some centres men are tested with words containing some a preponderance of high frequency, others of low frequency components and they may be failed, for example, if they cannot hear the high frequency words at 20 feet. At other places candidates are passed because they can hear some of the words at 20 feet. The inconsistencies in the present method of testing could be enlarged upon still further but enough has been said to show that there is very little standardization in the application of the present test. Whilst these inconsistencies have little importance for the vast majority of candidates who have "normal" hearing and are capable of passing the test under almost any conditions, they are important for the borderline cases who might be failed at one examining centre but would be passed at another.

## 2. Requirements of a New Test

A new test must, then, fulfil two primary requirements. It must constitute a measure of the candidate's hearing ability when working in "real life" conditions and it must be applied in strictly standardized conditions so that results from different examining centres may be comparable.

Flying conditions impose certain limitations on communication. In the first place, signals have always to be delivered through electri-

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channels terminated in some transducing unit. Secondly, the presence of a high level of ambient noise in aircraft makes it necessary to work with audible signals of considerable intensity. Even when signals are what is normally described as "faint", their absolute level is always considerably above threshold in quiet. Thus the type of hearing ability which is really required of aircrew personnel is the ability to hear signals well above threshold but in an unfavourable signal/noise ratio. No attempt has ever been made to correlate this ability with the ability to hear the whispered voice at given distances. It is indeed unlikely that a complete correlation would appear between these two quantities since it is well known that there are types of deafness in which the hearing defect is apparent only for sounds near threshold, i.e. the hearing at some supra-liminal intensity is equal to normal, and other types which, for masking noises of a particular character, will convert an unfavourable signal/noise ratio into quite a reasonable one. It is clear that a more suitable test for aviation candidates would be one in which high level signals were masked to some considerable degree by an accompanying noise.

If this principle is admitted, the only further requirements are that the test should be given under standardized conditions and that it should be validated by reference to personnel who are actually engaged on operations. The conditions must be so controlled that results given by the test at one time and place shall be strictly comparable with those given at any other time and place. This involves rigid control of the material used for the test, of the loudness of the signals and the masking noise delivered to the candidate, and the exclusion of interfering ambient noise. Speech signals are obviously the most suitable material for such a test and the manner in which speech can be used to form standardized tests is discussed in the next section.

### 3. Articulation Tests as the Basis of a New Test

A well established technique for the measuring of the reception of speech employs various forms of "articulation test". The principle is that continuous speech may be considered as made up of different units—sentences, words, syllables and sounds, and there is general agreement that the term "articulation" be taken to denote the percentage of sentences, words, syllables or sounds correctly received by the listener in given conditions. Up to the present, articulation tests have been used almost exclusively for the testing of apparatus but there is obviously no reason why they should not be adapted to the testing of a listener's ability\*. When the tests are used for measuring the articulation of communication systems there is always considerable difficulty in standardizing the performance of the listeners so that an unalloyed measure of the difference between systems may be obtained. It should, at least

\* A series of sentence and sound articulation tests were devised by Fry and Kerridge in 1939 for testing the hearing of speech by deaf people (see *Lancet*, January, 1939).

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theoretically, be an easier task to measure the difference between individuals whilst keeping the listening conditions uniform

## a TYPES OF TEST

### 1a *Sentence articulation tests*

A sentence articulation test is a test designed to measure the percentage of sentences correctly received by the listener. Most workers in this field amend the definition of sentence articulation and say "the percentage of sentences of which the *sense* is correctly received", thus allowing for minor verbal errors which do not materially alter the sense. While this seems to be the most sensible way to regard sentence articulation, it does bring in the possibility of variations in the judgment of the people marking the responses to the test, since it is not always easy to agree when the sense of the sentence has been materially altered. However, it is possible to get over this difficulty by somewhat modifying the technique of marking (see p 161). A number of different types of sentence articulation test have previously been used. The following are the most common.

- 1 Question and answer. A series of simple questions is sent to the listener who is deemed to have received the sense of the question correctly if he gives what appears to be a sensible reply.
- 11 Simple sentences. A large number of short sentences is read to the listener who records his reception of them either by writing them down or by speaking them back to the speaker, who checks the accuracy of the reception. Articulation tests usually have to be carried out in difficult acoustic conditions and if the second method of recording is used it is often necessary to provide an independent high-fidelity channel to carry the listener's reply. In any case, the method of writing down the sentence is certainly safer if also rather more laborious.

When the present research was begun, it was accepted as axiomatic that a measure of a listener's sentence articulation over a given system in given conditions was the nearest one could get to a direct measure of his ability to use that system for listening to current speech. It was further adopted as a basic principle that a reasonably close correlation must be proved between the results of sentence articulation tests and those of any other form of test which might be used before the validity of the latter could be accepted.

### 2a *Word articulation tests*

A word articulation test is one designed to give the percentage of words correctly received by the listener. It is commonly understood that in this type of test the words should be sent either without linguistic context or in a neutral context, i.e. they should be sent as isolated words or in a carrier sentence which gives no clue to the meaning of any test word. The selecting of words for these tests is not an easy matter. Theoretically, the frequency of occurrence of words in the test should

reflect their frequency of occurrence in the kind of speech which is to be sent over the system. To devise a test conforming to this principle would necessitate the long and laborious task of making word counts for various types of material. If it is assumed that the system will be used for all kinds of speech material, then it is possible to use some standard word count such as that made by Dewey\* for American English. Unfortunately, no such count exists for British English.

An alternative method is to base the selection of words on the frequency of occurrence of sounds in current speech. It can be argued that words are recognized chiefly by means of the recognition of speech sounds and if therefore we make a selection of words which are reasonably familiar and in which the distribution of sounds corresponds to that of current speech, we shall have a test which is likely to give a reliable measure of word articulation. Even so, a further complication is added by the importance of rhythm for the recognition of words. This factor can be ruled out by using monosyllables exclusively but a test of this character is of doubtful validity as a means of measuring word articulation since it takes no account of the occurrence of different rhythmic patterns.

### 3a. *Syllable articulation tests*

Most so-called syllable articulation tests are in reality sound articulation tests (see section 3 : 4a), that is to say they bear very little relation to "syllables" in the linguistic sense of the term and are really a particular form of sound articulation test. If we take a passage of connected speech and examine its component syllables we find that they differ not only in their sounds but also in the stress and pitch which are used in pronouncing them. These last two factors have a great effect on the recognition of the syllables and no test could be considered a true syllable articulation test which did not allow for these factors. No attempt has ever been made to devise such a test and indeed it is very doubtful whether such an undertaking would ever be worth while. Probably the results of such a test would add very little to the information which can be obtained more easily by means of sound, word and sentence tests.

The "syllable" articulation tests in present use consist of arrangements of speech sounds to form meaningless syllables; these may be of the form consonant-vowel-consonant (CVC), vowel-consonant (VC), or consonant-vowel (CV). The frequency of occurrence of sounds in such a test may or may not be weighted in accordance with the frequency of occurrence of the sounds in current speech. The test is marked by marking any one syllable right or wrong. Experience in various laboratories has shown that the scores for this type of test tend to be lower than those for a sound articulation test possibly because in one test the probability of getting a complete syllable i.e. a particular group of

\* Dewey, C. "Relative frequency of English speech sounds" (Harvard University Press, 1923).

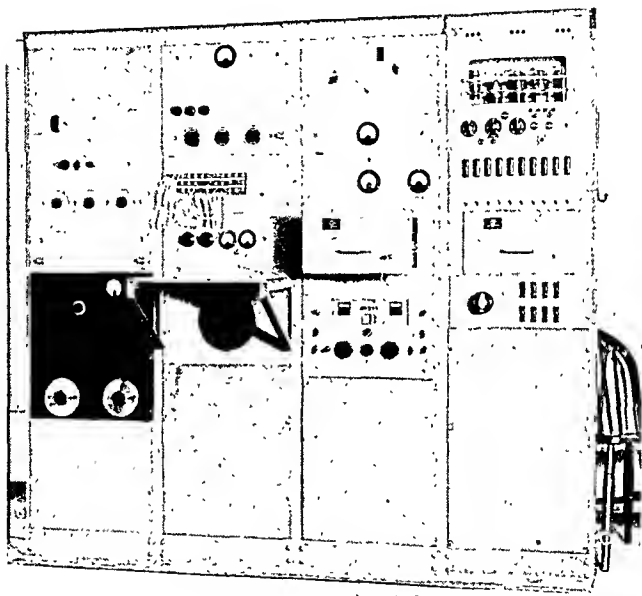


FIG. 1.  
General view of rack-mounted equipment.



to examine the other types of articulation tests to find out which was the most suitable, bearing in mind always that it was necessary to demonstrate a significant correlation between the results of a selected test and those of sentence articulation tests.

One type of test had to be ruled out of consideration, the type of sound articulation test which employs meaningless syllables. This kind of test can only be used with trained listening crews who have been taught some systematic method of writing down the sounds which they hear. In a hearing test naturally there can be no question of practice for the candidate and the result will be expected from his first attempt.

The types of test left for use in the experimental work which is now to be described are therefore sentence articulation tests as the direct measure of listening aptitude and forms of word and sound articulation tests with meaningful syllables as possible alternatives.

## 4. Equipment for Experimental Tests

In this section a general description will be given of the apparatus used in the experimental investigations leading up to the development of a new and more satisfactory hearing test. It was decided at the outset that in order to maintain standardized testing conditions all articulation tests should be recorded on gramophone discs and reproduced electrically. Most of the electrical equipment required was mounted on the standard four bay Post Office rack shown in the accompanying photograph, Fig. 1. Wherever possible the input and output impedances of each unit were fixed at 600 ohms, so that they could be connected together directly to form any desired channel. All connections were made on a jack panel using short screened leads. This arrangement was found to be quite satisfactory for most purposes, the small amount of hum induced in the lines being insufficient to interfere with our tests.

### a. PROVISION OF THE NOISE BACKGROUND

For subsequent experiments we require to be able to produce a noise field similar in frequency and overall level to that existing in a typical modern Service aircraft. Two methods for producing such noise suggest themselves. In the first the actual noise in the fuselage of an aircraft in flight is recorded and reproduced in the testing room, frequency correction being applied to compensate for any loss during recording. In the second method the noise is produced synthetically by amplifying suitably modulated electrical oscillations.

The second method has certain advantages, notably ease of production and control, but it is possible that the resultant noise, though satisfactory from the point of view of level and characteristic, may not sound like an aeroplane engine. It was felt that a noise which really gives the impression of an aeroplane in flight would be preferable to one which does not sound so realistic. Another argument in favour of using the recorded

## Testing Hearing Efficiency of Aviation Candidates

noise is that there is in existence a standard Service "noise generator" which is used for providing background noise for various types of synthetic training. There did not seem to be any reason why this generator, which makes use of an engine noise recording, should not be satisfactory for our purpose, and it was therefore decided to use it as the basis of our standard aero-engine noise. The steps in the development of the final satisfactory noise will be described in some detail in order to give an idea of the difficulties which were encountered in obtaining an adequate reproduction of aero-engine noise.

The first requirement was a testing booth with sound absorbing walls which would confine the noise. The internal dimensions of the booth which was constructed for us were height 9 feet, length  $5\frac{1}{2}$  feet, breadth 4 feet. No elaborate sound proofing was attempted as it was considered sufficient to reduce the noise outside the booth to a level which did not cause annoyance to other occupants of the building. The walls consisted of two layers of Celetex boarding separated by a layer of glass wool about 4 inches thick and the floor and ceiling were also padded with glass wool. The observation window consisted of two layers of glass about 2 inches apart. It was found that the reduction in overall level of the noise afforded by such a construction is approximately 20 db.

The noise generator as issued to the Service consists of a scanning unit, power amplifier and loudspeaker. A close-up photograph of the scanning unit is shown in Fig 2. A light beam is focused on an engine noise sound track on a glass disc mounted horizontally on the motor shaft. The modulated beam acts upon a photo electric cell and the resulting voltage variations are amplified and transmitted to a large moving coil loudspeaker in the testing booth. The sound track was produced by recording on the ground the noise of a Lockheed Hudson bomber after transmission over a high-fidelity radio link. The original recording was made on a direct recording disc and a particularly uniform section was then re-recorded photographically on a sensitized glass disc in the form of a continuous track. Four types of noise, corresponding to different flying conditions (normal cruising speed, maximum boost, etc.) were recorded in this way. The output of the photo-electric cell goes to a straightforward resistance-capacity coupled valve amplifier capable of delivering 50 watts into an output circuit of 600 ohms impedance for an input voltage of 11 millivolts. The output of this amplifier is led through an impedance matching transformer to the energized Pamphonic moving coil speaker in the booth. This loudspeaker is capable of handling an input of 20 watts. The overall diameter of the stiff paper cone is 16 in. and the impedance of the moving coil 10 ohms. The complete noise channel is shown schematically in Fig 3 and Fig 4 shows a photograph of the interior of the booth.

The sound track corresponding to normal cruising speed was selected

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as being most suitable for our purpose. Intensity and frequency characteristic measurements were made on the noise generated in the booth using the General Radio sound level meter and the S. T. & C.

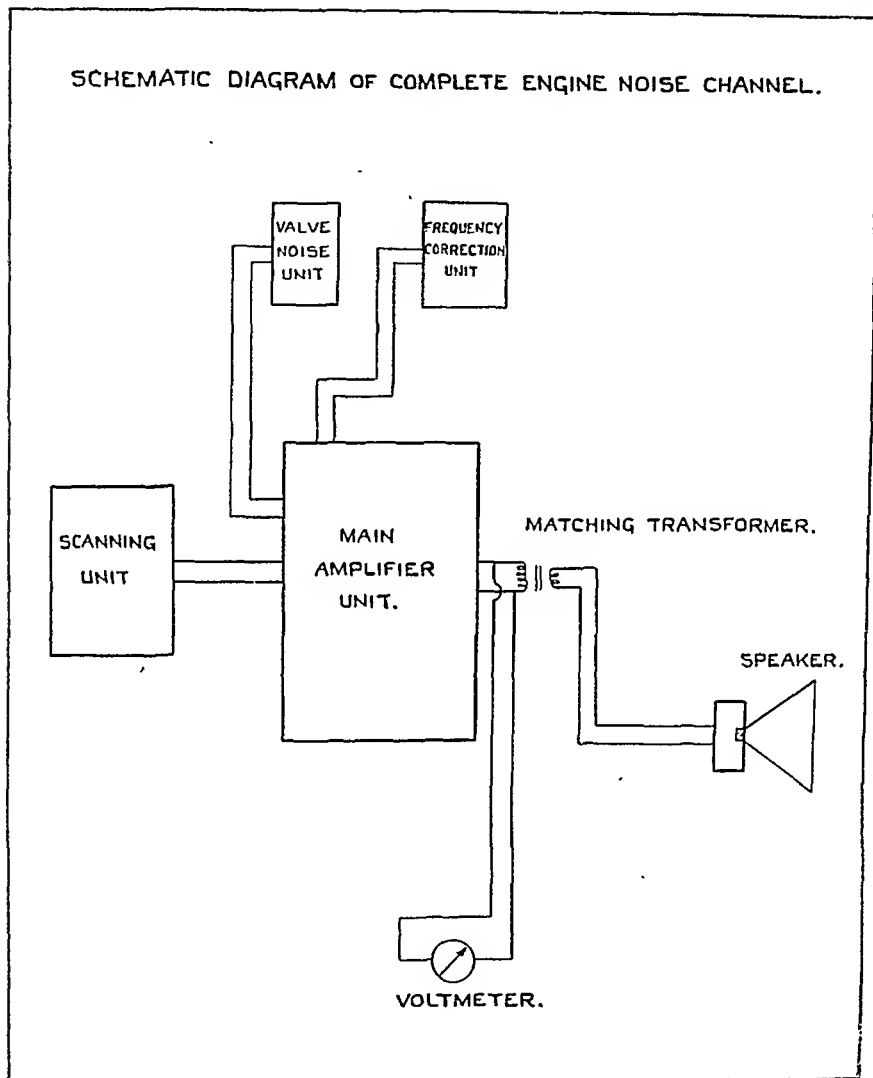


FIG. 3.

noise analyser described in section 4d. The two microphones were mounted side by side on the axis of the speaker and about 18 in. from the centre of the cone. The gain of the noise amplifier was then increased as much as possible without producing undue flapping of the speaker diaphragm. At this level the G.R. meter gave a mean reading of 110



FIG 4  
Interior of testing booth



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phones. The intensity was not entirely uniform throughout a revolution of the glass disc but the difference between the extreme values was not more than 6 db. The intensity of the noise in half-octave bands was measured on the S. T. & C. noise analyser. The resulting spectrum is

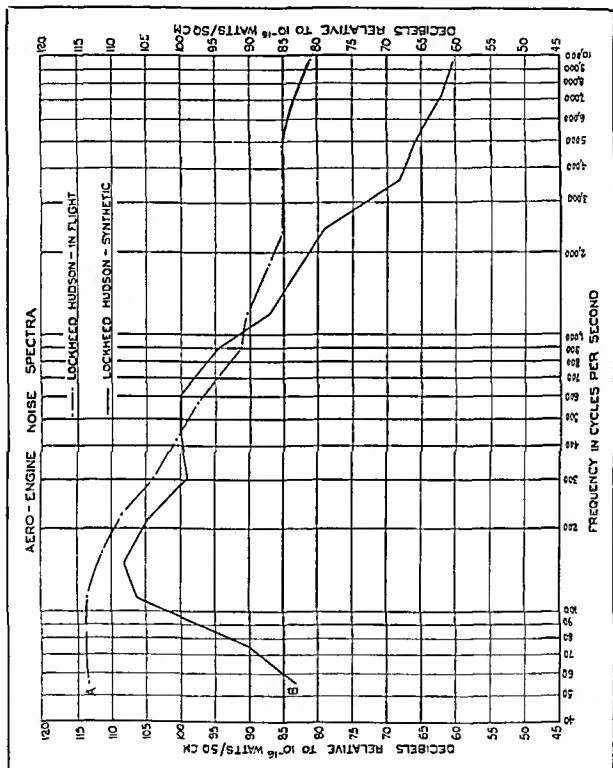


Fig. 5.

shown in Fig. 5. The spectrum plotted inside the cabin of a Hudson in flight, using the same meter, is shown for comparison. It can be seen that our recorded noise is very similar to the actual noise in the region 150-1200 c.p.s. but that above and below this band the intensity falls off considerably. In order to compensate for this falling off a frequency

these high frequency fluctuations were fed through a potentiometer into the grid circuit of the first stage of the main amplifier. The circuit diagram of this synthetic noise generating unit is shown in Fig. 8. The

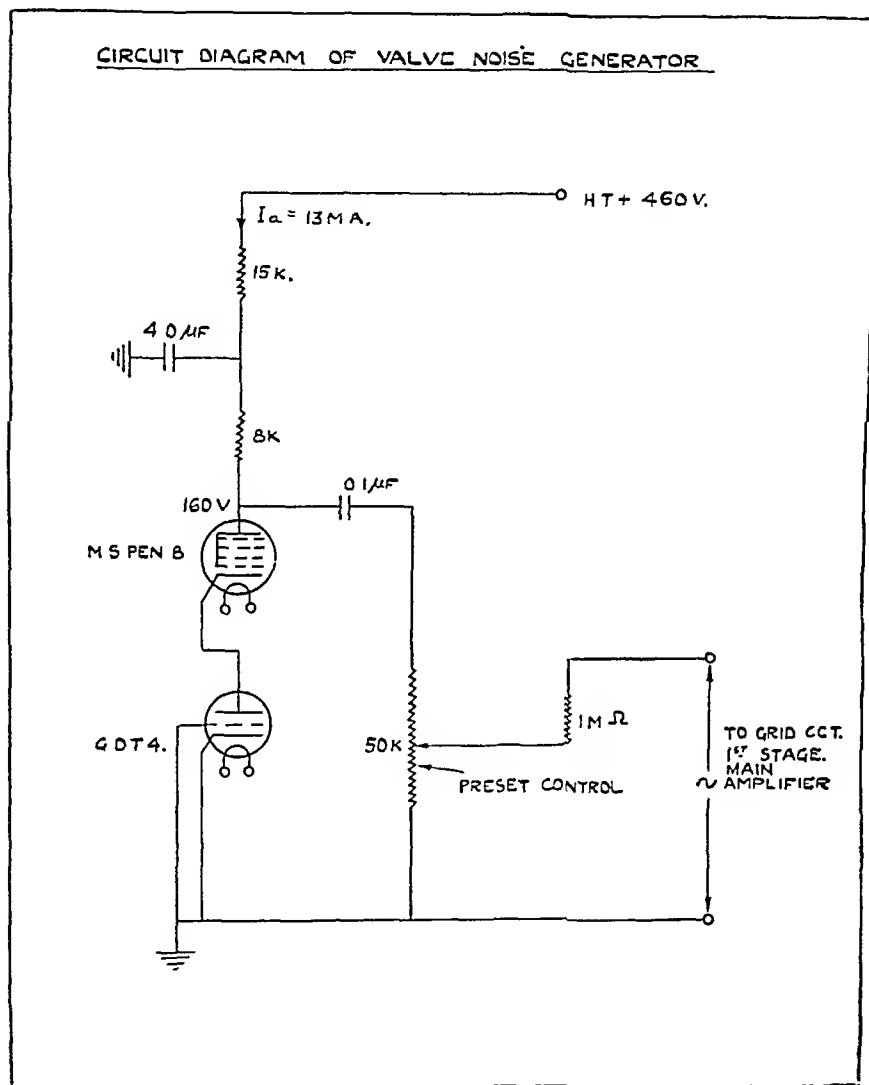


FIG. 8.

pentode valve is used as a diode and merely provides a convenient method of limiting the current carried by the gas-filled tube. The D.C. high tension supply was taken from the anode circuit of the second stage of the amplifier.

# Testing Hearing Efficiency of Aviation Candidates

The frequency characteristic of the resulting composite noise was plotted with varying proportions of synthetic noise until a setting of the potentiometer was found at which the artificial and true Hudson spectra agreed fairly well over the range 100-10000 c p s. All attempts to raise the intensity below 100 c p s produced flapping of the speaker cone which introduced a loud rattle. It appeared that the speaker was incapable of handling greater intensities at these frequencies and so the attempt to apply bass correction was given up.

This particular form of the noise was then accepted as our standard aero engine noise for all subsequent experimental work. Its spectrum is shown in Fig 7 for an overall intensity of 101 phons. It can be seen that the agreement with the true spectrum is very good except at the extreme low frequencies.

In order to avoid having to measure the noise level with the G R meter every time the generator was switched on a small meter was connected into the output circuit of the amplifier and calibrated against the G R meter. This arrangement also enabled us to keep a check on the constancy of the noise level during an experimental run.

## b RECORDING CHANNEL

A short description will now be given of the recording channel which was used in producing the master records for all the test discs required for the experimental articulation tests and for the final test.

The speech channels in use in Service aircraft transmit a restricted range of frequencies and may be considered in general as low fidelity systems. Since the object of the new test is to measure the ability to use such a system it would appear at first that a similar channel should be used in applying the test. On reflection, however, it was decided that a reasonably high fidelity system should be used for the experimental work for the following reasons. It was important to discover whether a degree of hearing loss, as measured by pure tone audiometry, would decrease a subject's ability to hear speech when in the presence of noise. Now if a channel with restricted frequency range, say from 500-3000 c p s, had been used, it is possible that a subject with a hearing loss falling outside this range would be in just as favourable a position as a subject who had no loss at all. If a deaf subject scored as high in an articulation test as a 'normal' subject, there would still be the possibility that this was due to the fact that his hearing loss lay outside the range of frequencies transmitted. By extending the frequency range it was hoped to make the tests more selective.

It was therefore decided to aim at a reasonably high fidelity channel for both the recording and the replaying of the speech material to be used in the articulation tests.

The recording channel consists of a mixer unit, an attenuating network,



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a high-gain amplifier and a recording machine, as shown schematically in Fig. 9. The mixer comprises three independent variable ladder attenuators which are connected to a common output. These attenuators

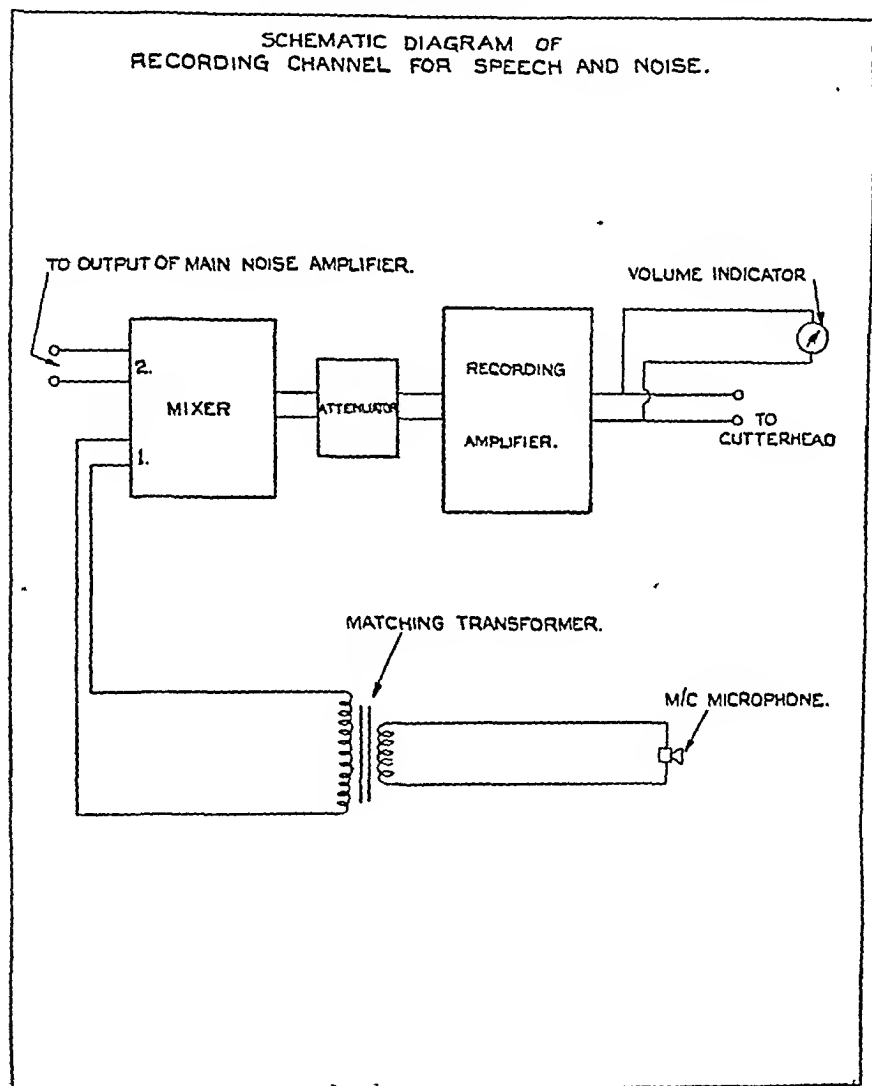


FIG. 9.

which are graduated in steps of 2 db. enable us to mix three independent signals in varying proportions for recording. The output from the mixer unit is connected to the main attenuating network which consists of a series of T-type attenuators and covers a range of 0-60 db. in steps of 1 db. The characteristic impedance of both these units is 600 ohms. The

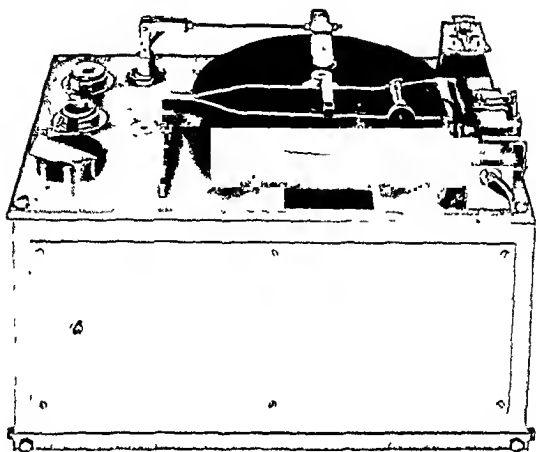


FIG 10  
MISS recording machine



# Testing Hearing Efficiency of Aviation Candidates

resistance capacity coupled recording amplifier gives an amplification of 84 db and the power developed across the cutter-head when recording is of the order of 5 watts. When delivering this power the total harmonic distortion of the amplifier is 5 per cent. The frequency response of the amplifier can be varied by means of treble and bass correction circuits, embodied in the amplifier. The input impedance of the amplifier is 600 ohms and the output is matched to the recording cutter-head, impedance 2,000 ohms.

The recording machine (see Fig 10) used for cutting the test discs was made by the M S S Recording Co. It consists of a heavy metal turntable, a needle armature cutter-head, supported in a traversing arm, and an electric motor which, through reduction gears, drives both the turntable and the traversing mechanism. The turntable speed is 78 r p m and the traversing speed is such as to produce 100 grooves to the inch. The actual cutting of the disc is done with a steel cutting stylus, held in the cutter-head. The position of the cutter-head in the traversing arm can be adjusted so as to vary the angle of the stylus with respect to the disc and the pressure upon the point of the stylus. The machine is normally set up so that the stylus trails at an angle of about  $5^{\circ}$  from the vertical and so that the width of an unmodulated groove is 0.006 in, the wall between adjacent grooves is therefore 0.004 in thick.

Speech signals for the tests were recorded through a Standard Electric moving coil microphone, type No 4017A.

The frequency response of the recording channel from microphone to disc is shown in Fig 11. It is estimated that the total harmonic distortion is of the order of 10 per cent.

## c REPLAY CHANNEL

This section will be divided into two parts. In the first a description is given of the channel through which the speech was transmitted in the series of preliminary articulation tests, in the second the replay channel for the final test is described in some detail.

### 1c *Replay channel for speech*

In the first series of tests the subject was seated in an external noise field similar to that encountered in Service aircraft. The provision of this noise background has already been described in section 4a. The speech was then transmitted to the subject over a reasonably high fidelity channel. The reasons for employing a high-fidelity channel in preference to a low-fidelity system of the type used in Service aircraft are outlined in section 4b.

This high-fidelity speech channel consists of a pick-up, an attenuating network, a high-gain amplifier and a headset. The pick up is a lightweight low impedance unit of the standard needle-armature type, supplied by the E M I Co. The weight on the pick-up needle is approximately

1.5 oz. The output of the pick-up passes through a matching transformer to the main attenuating network used in the recording channel already described. The signals are then led to a variable gain resistance-capacity coupled amplifier which has a sensibly flat frequency response over the

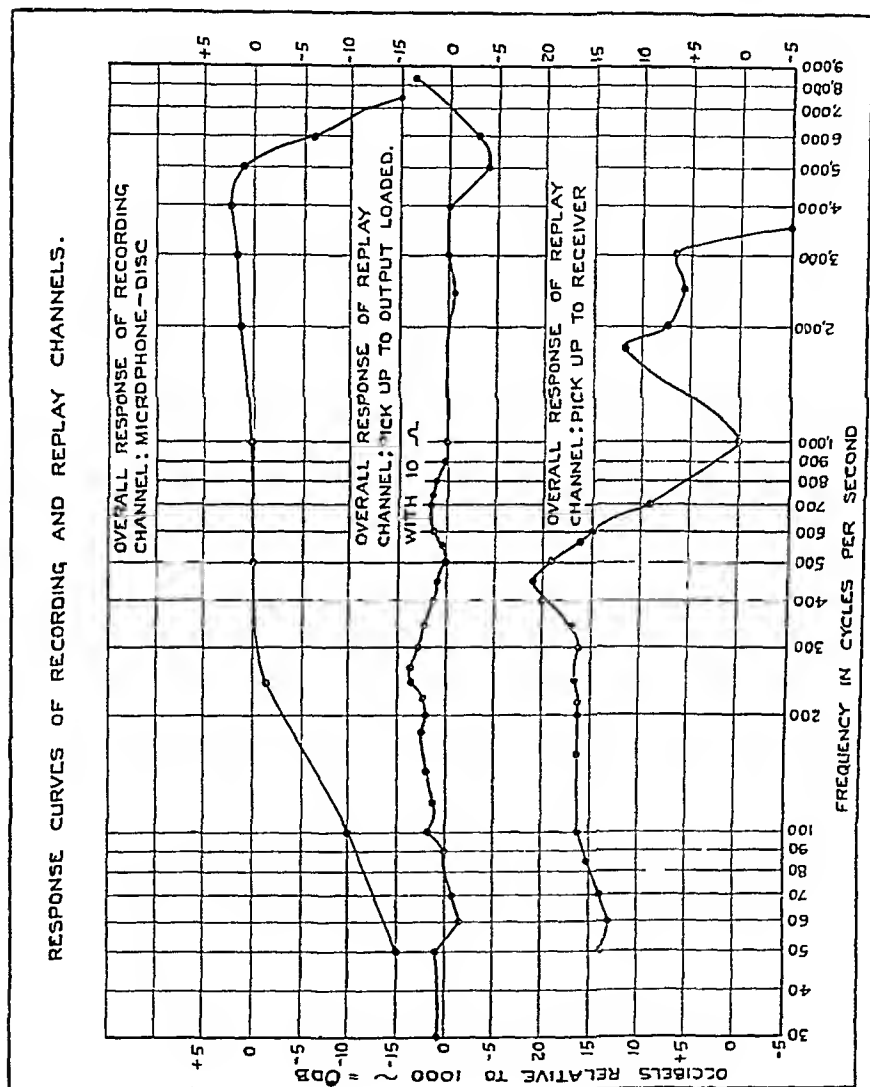


FIG. 11.

range 100-8000 c.p.s. The output of the amplifier is connected to a pair of British Goodman moving coil receivers which are located inside the testing booth.

The frequency response of the complete replay channel from pick-up to receivers is shown in Fig. 11. The major variations in the overall

# Testing Hearing Efficiency of Aviation Candidates

response curve are due to the response of the receiver. At the levels used in these articulation tests the total harmonic distortion of the complete replay channel is not greater than about 2 per cent. As the harmonic distortion of the recording system from microphone to disc is about 10 per cent it follows that the total distortion introduced into the speech during recording and subsequent replay is of the order of 12 per cent.

## 2c *Replay channel for masked articulation test*

At a later stage in the experimental work it became necessary to test a large number of partially and fully trained flying personnel, using a modified form of test which will be referred to as a masked articulation test. In this test the subject received both the engine noise and the speech signals through the telephone receiver. It was decided to construct portable testing equipment which could be taken to operational and training stations and would be similar in character to the standard replay channel described in the previous paragraph. This portable equipment took the form of a compact combined gramophone and amplifier designed to operate from A.C. mains. The circuit diagram is shown in Fig. 12 and Fig. 13 shows the layout of the machine. This portable testing equipment will in future be referred to as the gramophone audiometer. It is shown in operation in Fig. 14.

The electric motor, turntable, pick-up and amplifier are similar to those used in the standard replay channel, but the amplifier is provided with a pre-set gain control so that the output level cannot be altered accidentally. The output of the amplifier is led through a multi-core cable to a junction box by means of which connection is made with ten pairs of Goodman moving coil receivers mounted in Type C insulated headbands. The impedance of a pair of receivers connected in series is 100 ohms and the ten pairs connected in parallel therefore present an impedance of 10 ohms to the output of the amplifier. Provision is made for feeding the signal to any number of pairs or of single receivers. In order to do this a switching arrangement is incorporated in the lead to each receiver so that when the receiver is disconnected it is replaced by an equivalent resistive load and the output of the amplifier therefore remains independent of the number of receivers in the circuit.

It would have been possible to avoid the use of the multi-core cable and the associated plugs and sockets by locating the switches on the headbands. It is, however, preferable to keep the switches under the control of the operator rather than the candidate. They are therefore located in the audiometer itself and can be seen on the right of the panel shown in Fig. 14.

The H.T. supply to the valves can be checked during operation by means of a meter and associated switch. This meter is also used to

check the overall gain of the system. To carry out this measurement the telephones are replaced by a resistive load of 10 ohms ; the meter is then connected across this load and measures the voltage developed from

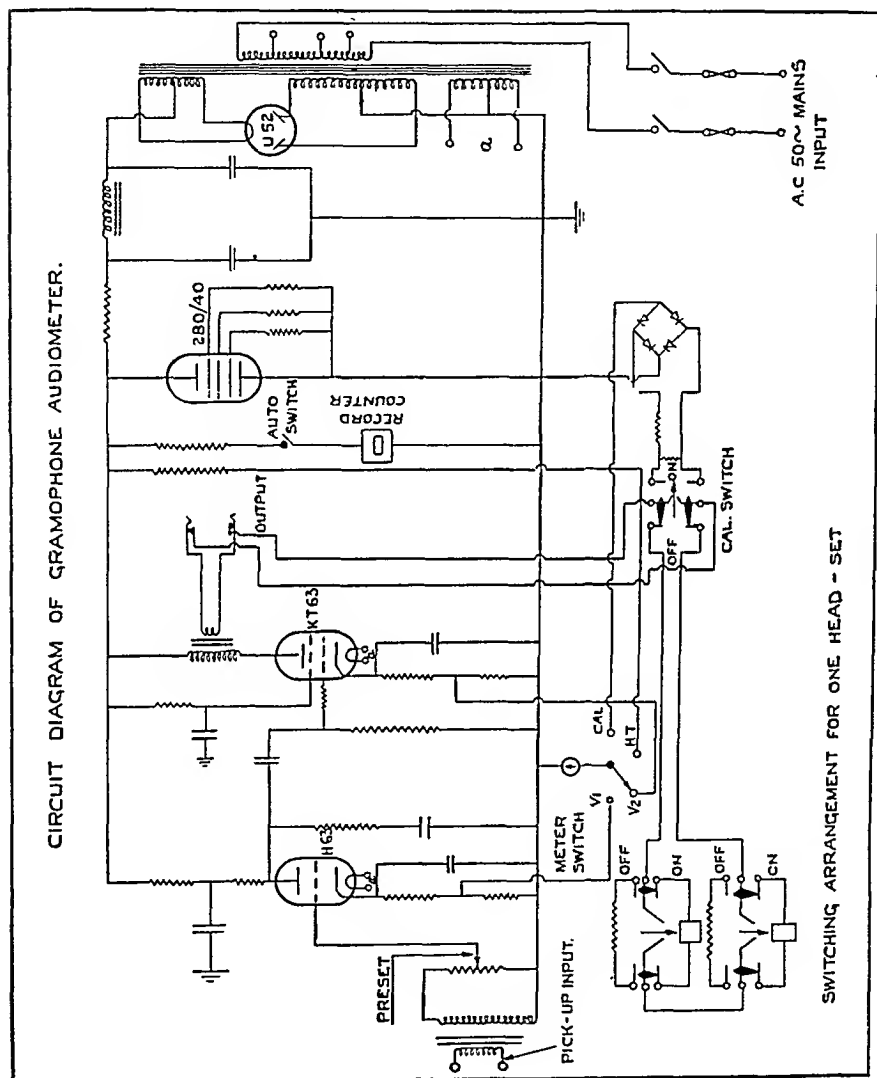


FIG. 12.

a standard pure tone recording. Calibration switches are provided for making the connections necessary for this measurement.

An automatic counter is incorporated for reading the number of times each disc is played. This counter is actuated by an arm attached to the pick-up which completes an electrical circuit each time the pick-up enters the run-out groove at the end of a disc.

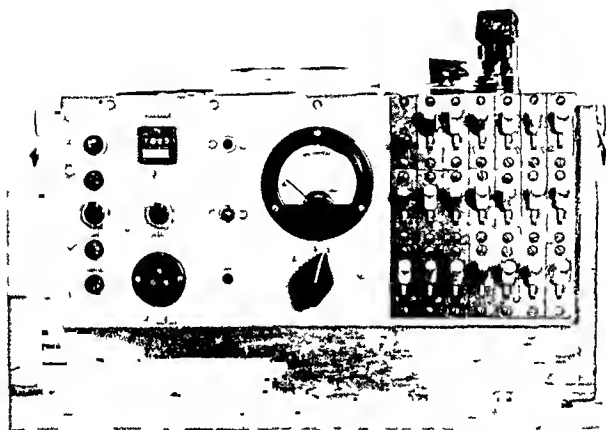


FIG 13  
Close up view of gramophone audiometer





FIG 14  
Gramophone audiometer in operation

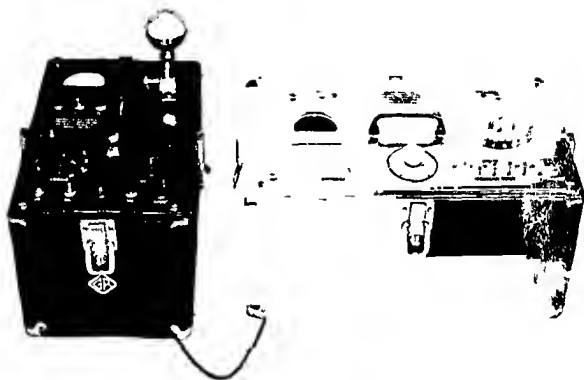


FIG 15  
General Radio Sound Level Meter and Sound Analyser

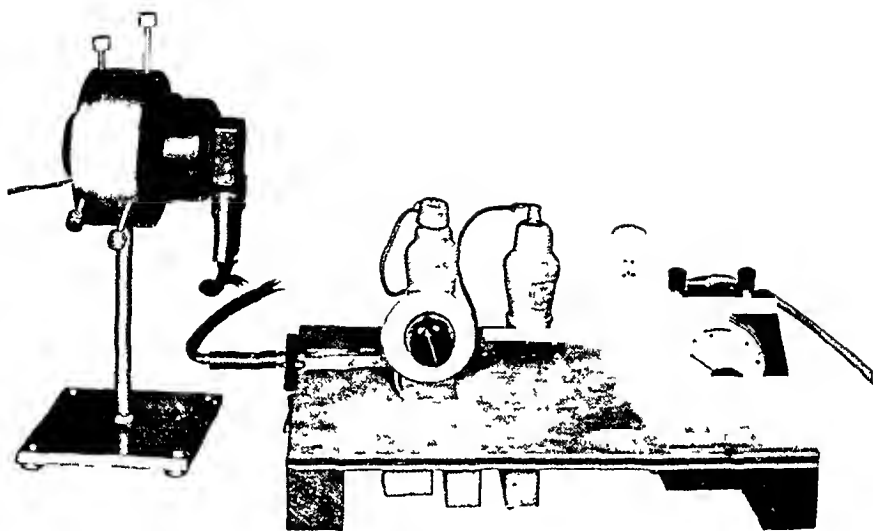


FIG 16  
Valve voltmeter and coupler

# Testing Hearing Efficiency of Aviation Candidates

The total harmonic distortion of the system from pick-up to receiver is of the order of 2 per cent

The equipment described in this section will serve as a prototype for the audiometers which will be required in the event of the test's being accepted by the Service

## d ANCILLARY EQUIPMENT

### (a) *Noise level meter*

All noise level measurements were made with the General Radio Sound Level Meter, type No 759B, shown in Fig 15

### (b) *Noise Analysers*

The spectra of the engine noise fields were plotted using a Standard Telephones & Cable Co noise analyser This analyser consists of a microphone, attenuators, a variable filter unit, a battery amplifier and an output meter The filter unit covers the range 37-12800 c/s in overlapping octave bands The analyser was calibrated by summing the intensities over adjoining octave bands and equating the result to the overall level as measured on the G R

A G R Sound Analyser type No 760A, was later obtained and used for measuring the distortion in the recording and replay channels This analyser is shown connected to the Sound Level Meter in Fig 15

### (c) *Standard coupler and microphone*

The efficiencies of the telephone units were compared by coupling each receiver to a microphone and measuring the open circuit voltage developed across the microphone when a known signal was applied to the receiver A coupling unit was constructed having a cavity of volume 6 c.c. which is approximately the volume of air enclosed between an earpiece and the tympanic membrane This coupler was turned out of solid brass cylinder, the dimensions of the cavity being length 2.0 cm, diameter 1.96 cm Provision is made for clamping the receiver and the standard microphone firmly against opposite ends of the cylindrical cavity Each end of the coupler is covered with a thin layer of rubber to prevent leakage of air when the receiver and microphone are clamped in position

The Standard Electric moving coil microphone mentioned in the section dealing with recording, was used in conjunction with this coupler and the open circuit voltage developed across this microphone measured on a sensitive valve voltmeter

### (d) *Valve voltmeter*

The voltmeter on which the voltages developed across the S.E. microphone were measured had an input impedance of 1 megohm and consisted of a two stage high gain valve amplifier coupled to a cathode follower which served to prevent the low impedance indicating meter

from short circuiting the second stage of the amplifier. In this way it was possible to obtain almost the full amplification of the two valves. This voltmeter is shown in Fig. 16 connected to the S.E. microphone and standard coupler.

(e) *Pure tone oscillator.*

A Birmingham Sound Reproducers beat frequency oscillator, type number LO 800, supplied the pure tones used in these experimental investigations. The output of this oscillator when optimally loaded is constant to within 2 db. over the frequency range 50-10000 c.p.s., and the total harmonic distortion is less than 1 per cent.

(f) *Pure tone audiometer.*

The pure tone audiometer used throughout was a Western Electric audiometer, type 6A.

## 5. Experimental Articulation Tests

It has been said in section 3, p. 145, that it would be necessary to seek an alternative to sentence articulation tests as a basis for the new hearing test. It is proposed in the present section to describe the experimental work which was undertaken in order to decide upon a satisfactory alternative. This work falls into two parts: (a) a preliminary series of experiments designed to determine whether a sound or a word articulation test would be more satisfactory as an alternative to sentence tests; this led to the conclusion that a sound articulation test was likely to prove more satisfactory, and (b) a further series of experiments to reaffirm the correlation between sentence and sound articulation scores and to determine the range of scores to be expected from "normal" untrained subjects in these tests. The plan adopted in describing these experiments is the following;

- i. The test material used in the articulation tests is described, together with the marking of the responses.
- ii. The conditions and technique of testing are described.
- iii. The results of the tests are discussed.

### a. TYPES OF TEST USED.

#### 1a. *Sentence articulation tests.*

The sentences used for these tests are those mentioned above (p. 143) as having been designed to test the hearing of speech by deaf people. Each test consists of 25 syntactically simple sentences, dealing with commonplace ideas and using only the simplest vocabulary. A sample of these sentences is given in Appendix II, p. 197. It will be obvious from this sample that no ordinary person would have any difficulty in grasping the ideas expressed or would find any of the words unfamiliar. Since the number of sentences used for each test was small it was desirable to ensure that every test contained a proper representation of the speech

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sounds of English No sound count of British English speech was available so a count was made over a total of 17,000 sounds occurring in phonetic transcriptions of current English speech The occurrence of sounds in the sentence tests was compared with the values obtained and the result

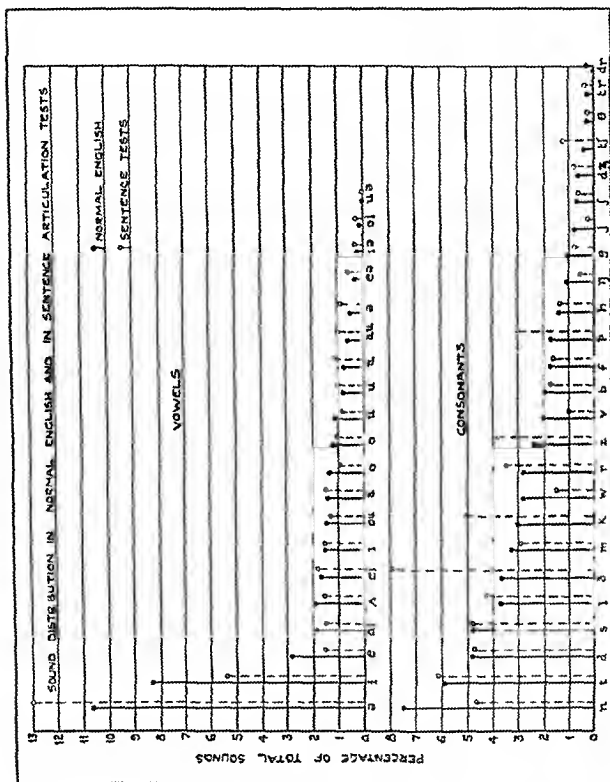


Fig 17

is shown in Fig 17. The high occurrence of a and ð in the tests is due to the frequent use of "a" and "the" in the sentences. These words were given no value in the marking of the tests.

In order to standardize as far as possible the marking of the sentence tests by different people it was decided to modify the usual system of

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allowing one mark per sentence. Since each subject listened to 25 sentences only it would have been necessary to multiply scores by four in order to obtain a percentage on the one-mark-per-sentence system and it seemed preferable from every point of view to introduce a system of partial credits for the sentences. In each sentence, therefore, one mark was allowed for every word which helped to carry the sense of the sentence, with an average of four marks for each sentence. This provided not only a well standardized but also a more sensitive method of marking. It should be noted that this method in no way alters the character of the test as a sentence articulation test since the listener still depends on linguistic context for his understanding.

### 2a. *Word articulation tests.*

The word articulation tests used in these experiments were also taken from "Tests for the Hearing of Speech by Deaf People" (Fry & Kerridge). Each test consisted of a list of 25 monosyllabic nouns, all words which were likely to be familiar to the subject. Again in these tests care was taken that the sound distribution should approximate fairly closely to that of current English speech. The result of the sound counts is shown in Fig. 18. A specimen of the word lists is given in Appendix II, p. 197.

A single word test carried 25 marks, one for each word right, and the percentage score was obtained by multiplying the actual score by four.

### 3a. *Sound articulation tests.*

The sound articulation tests used for the first experiments were of the type described on p. 146. The words used by Harvey Fletcher were adapted to form two lists of words, one designed to test reception of consonants, both initial and final, and the other the reception of vowels. The consonant list was made up of two series of words; the words in one series consisted of an initial consonant plus the vowel *ai*, and in the other series of the sounds *wi* plus a final consonant. Each list used contained 30 words and in each word only one sound carried a mark, the initial consonant in the first series and the final consonant in the second series. The vowel list contained words made up of an initial *b* and a final *t*, with one of 11 vowels. In any one vowel list the word containing a given vowel was used twice so that a vowel list comprised 22 words. Again in this list only one sound, the vowel, carried a mark. Five alternative consonant and vowel lists were obtained by rearranging the two sets of words. A specimen of each type of list is shown in Appendix II, p. 197.

Each subject was given one consonant and one vowel test and from the results of these a sound articulation percentage was arrived at by combining the scores for the vowel and consonant tests.

## b. TESTING TECHNIQUE

### 1b. *Recording of material.*

The various lists of sentences and words were recorded with the

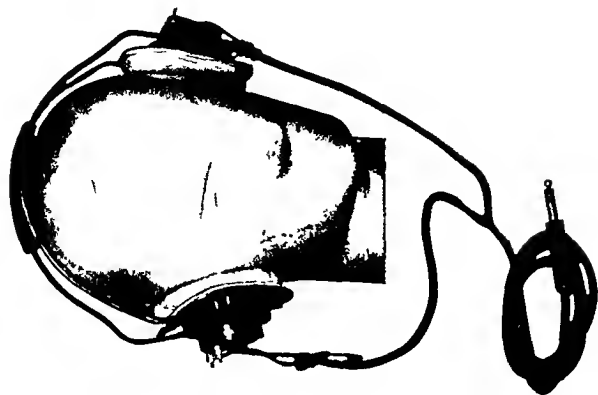
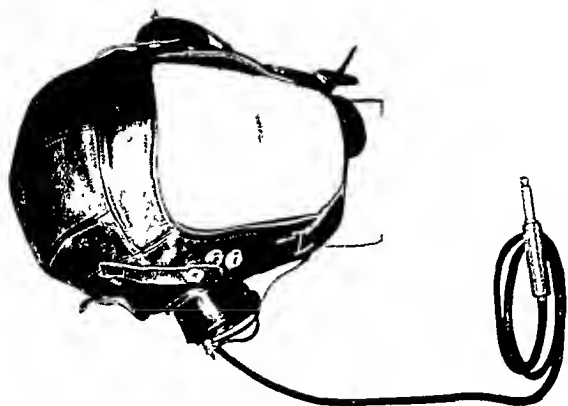


Fig. 19

Type C helmet and Type C insulated headband







## Testing Hearing Efficiency of Aviation Candidates

equipment described in section 4b. All the recordings were made by the same announcer who spoke at a fixed distance from the microphone and kept the overall level of his voice as constant as possible. While each disc was being cut, the speech was written down in front of the

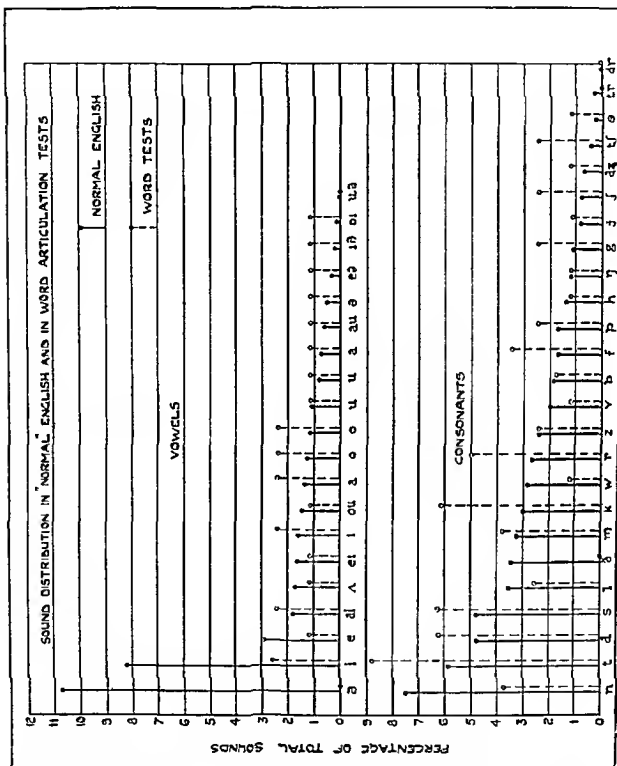


Fig. 18

announcer so that he could estimate the amount of time to allow between succeeding words and sentences. The writing speed was very slow so that sufficient time would be allowed for the least alert of candidates likely to be tested. A complete sentence list required two discs and two word lists were recorded on a single disc.

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Although the recording conditions were kept as constant as possible it was found that the level of the speech did vary slightly from disc to disc. In order to allow for this variation the whole series of test discs was replayed through a loudspeaker and one disc was chosen as the reference. Subjective determinations were then made by three trained listeners as to the amount of attenuation required on replay in order to bring the output of all discs to the level of the reference disc. Very good agreement was obtained in these judgments and the relative replay levels determined in this way were maintained during all subsequent tests.

For these tests it was decided arbitrarily not to play any pressing more than 30 times and to change the replay needle after each 30 playings. These are much less than the playing life given by the manufacturers of discs and needles and later tests have shown that we were justified in assuming that the articulation scores would not have deteriorated appreciably owing to wear of the disc or the needle after this number of playings.

## 2b. *External noise field.*

All the articulation tests were carried out in the standard aero-engine noise field described in section 4a. The mean overall level of the noise was set at 110 db. as measured on the G.R. Sound Level Meter and the constancy of this level was checked during the tests by watching the meter in the output circuit of the noise amplifier.

## 3b. *Protection against noise.*

In order to reproduce actual flying conditions as closely as possible, the subject should, when placed in the noise field, be afforded the normal protection from the noise, that is he should wear one of the Service type flying helmets. In the first series of tests, designed to measure the degree of correlation between the results of sentence and word, and sentence and sound articulation tests, one Type C Service flying helmet of medium size, fitted with a pair of British Goodman moving coil telephone receivers, was used for all subjects. Given the immense variety in the size, shape and layout of heads, it was manifestly impossible that the one helmet should provide an equally good seal against the noise for all subjects. But since in these experiments only a correlation was being sought, and since each subject did all three tests at one sitting without removing the helmet, it was felt that this factor should not unduly influence the correlation between the results. When the second series of tests was undertaken with the object not only of reaffirming a correlation but also of gaining information as to the range of scores to be expected from such a test in standard conditions, it was obviously necessary to control this factor. The Type C helmet was therefore replaced by a new type of headband (the Type C insulated headband) which had just come into use in Coastal Command. With this headband the position of the ear pads

# Testing Hearing Efficiency of Aviation Candidates

and telephone holders was adjustable so that for any head the earpiece could be fairly accurately positioned opposite the auditory meatus. Once this adjustment was made, the pressure on the ear pads was reasonably constant whatever the size or shape of the head. The Type C helmet

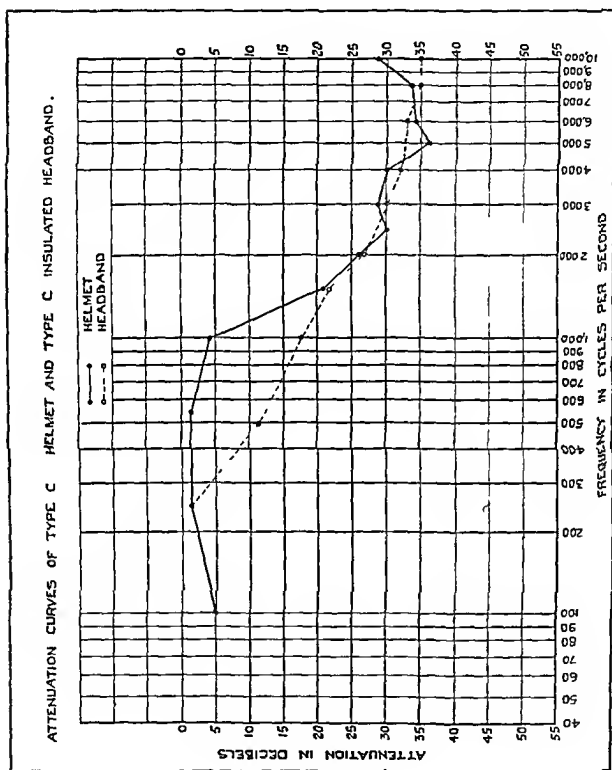


FIG 20

and the adjustable headband are shown in Fig 19, and the attenuation effected by the helmet and headband respectively are shown in Fig 20

In both series of tests the signal/noise ratio was selected by keeping the noise level constant and varying the speech level during some trial



# Testing Hearing Efficiency of Aviation Candidates

background of aero-engine noise and it was impressed upon him that he should endeavour to write down as much of each sentence or word as possible, using context as a guide in the case of sentences. It was found

Name *WINDSOR, C...* Date *25.5.42* Articulation *82%* Card *D*

1. <i>DISH</i> ✓	11. <i>BOOT</i> ✓	21. <i>FISH</i> ✓
2. <i>DATE</i> ✓	12. <i>SOAP</i> ✓	22. <i>—</i> X
3. <i>BUN</i> ✓	13. <i>—</i> X	23. <i>—</i>
4. <i>FEET</i> ✓	14. <i>FIGHT</i> ✓	24. <i>—</i>
5. <i>THOUGHT</i> ✓	15. <i>GLOVE</i> ✓	25. <i>—</i>
6. <i>BAD</i> ✓	16. <i>BAKE</i> ✓	26. <i>—</i>
7. <i>MOAT</i> ✓	17. <i>BOOT</i> ✓	27. <i>—</i>
8. <i>BIKE</i> ✓	18. <i>BACK</i> ✓	28. <i>—</i>
9. <i>—</i> X	19. <i>—</i> X	29. <i>—</i>
10. <i>BOUT</i> ✓	20. <i>THOUGHT</i> ✓	30. <i>—</i>

Correct *18*

Name *WINDSOR, C...* Date *25.5.42* Articulation *43%* Card *C*

1. <i>BUY</i> X	11. <i>—</i> X	21. <i>WITCH</i> ✓
2. <i>BUY</i> X	12. <i>WITCH</i> X	22. <i>SHOE</i> X
3. <i>WIG</i> X	13. <i>GUY</i> X	23. <i>FLY</i> X
4. <i>NIGH</i> ✓	14. <i>WIG</i> ✓	24. <i>WIND</i> X
5. <i>WILL</i> ✓	15. <i>WIND</i> ✓	25. <i>BUY</i> X
6. <i>BUY</i> ✓	16. <i>LIE</i> ✓	26. <i>SIGH</i> X
7. <i>RYE</i> ✓	17. <i>—</i> X	27. <i>WITCH</i> X
8. <i>WITCH</i> X	18. <i>WISH</i> ✓	28. <i>SIGH</i> X
9. <i>WHY</i> ✓	19. <i>SIGH</i> ✓	29. <i>WIN</i> X
10. <i>FISH</i> X	20. <i>GUY</i> ✓	30. <i>SHY</i> ✓

Correct *13*

FIG. 22.

Forms for sound articulation test.

that most of the subjects understood straight away what they were expected to do and co-operated fully in the tests. The method of marking the responses is treated in section 5a.

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## C. RESULTS OF TESTS

### 1C. *First series.*

In the first series of experiments one hundred subjects were tested with sentence, word and sound articulation tests. Most of these subjects were fully trained aircrew personnel and they included men with varying degrees of hearing loss. At this time we had little information on the influence of hearing loss on the ability to perform such a test and we hoped that by using subjects with widely differing audiograms we should obtain scores scattered over a fairly wide range for all types of test. The results of both series of tests show however that the scores from a sample of subjects with "normal" audiograms may scatter just as widely as those from a group of subjects with varying degrees of hearing loss. It was indeed soon apparent in this experimental work that it was difficult to predict from a subject's audiogram whether he was likely to do well or badly in an articulation test in a noise field.

Each subject was given one sentence, one word and one sound articulation test. Assuming a linear relation between the variates, the product-moment correlation co-efficients were calculated in the usual way for the sentence-word and the sentence-sound scores. These calculations gave a correlation co-efficient of 0.530 for the sentence-word scores and of 0.819 for the sentence sound scores.

This result showed that the correlation between sentence-sound scores was closer than that between sentence-word scores and it was therefore decided to carry out the sentence and sound tests only in the second series of experiments.

### 2C. *Second series.*

The next group of tests was undertaken with two objects in view, first to check the correlation between sentence and sound scores for a sample of untrained subjects and second to find out how the scores were likely to scatter for these subjects in both types of test. The subjects tested were 100 cadets from No. 1 Aircrew Receiving Centre, London, that is to say they were all men who had been selected for flying training and had therefore passed the 20 ft. hearing test and clinical examination at one of the Aviation Candidates Medical Boards. Pure tone audiometry was carried out on every subject and very few of them showed a loss of more than 15 db. at any one frequency. The hundred were given the sentence and sound tests in the conditions outlined in sections 4 a and 5 b.

The results of this second series of tests are tabulated in Fig. 23. The product-moment correlation co-efficient for the sentence-sound scores under these more rigidly controlled conditions has the value 0.706. This is rather lower than the value obtained in the first series of tests but it must be remembered that we are now dealing with completely untrained men and their performance is more likely to vary

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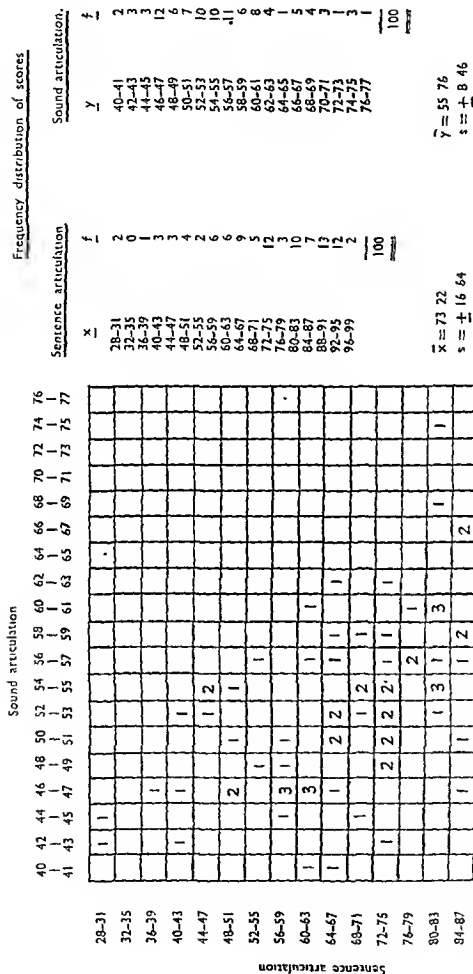


Fig. 23.  
Correlation between sentence and sound articulation in noise.



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from test to test than is the case with trained aircrew who are accustomed to listening to speech signals under conditions of acoustic stress.

The frequency distribution of the scores on the two tests shows that the sentence scores are much more widely scattered than the sound scores. This may be partly due to the fact that the sentence test requires a certain amount of intelligence in the piecing together of words imperfectly heard and therefore reflects to some extent the mental capabilities of the subject, whereas the sound test is a more direct measure of the ability to hear speech sounds under these special conditions.

As the sample is fairly large and the value of the correlation coefficient "r" is not too great, the standard error of "r",  $\sigma_r$ , has

been calculated from the formula  $\sigma_r = \frac{1-r^2}{\sqrt{N}}$ . This gives the value 0.050.

"r" is therefore equal to 14 times its standard error and the probability of getting this value of "r" from samples which are drawn from uncorrelated populations is quite negligible. There is, therefore, a significant correlation between the scores on the sentence test and those on the sound test, and we are justified in adopting the much shorter and much more easily constructed sound test as an index of a man's ability to hear connected speech in the presence of noise.

The results of these tests were particularly interesting in showing that articulation scores from subjects with "normal" hearing were likely to vary over a wide range and thus suggested that the ability to do well in an articulation test in noise is not correlated in any simple manner with threshold for pure tones. The only general tendency is for a subject with a low tone hearing loss to do well in the articulation tests. A more complete investigation of the relation between threshold hearing loss and scores in articulation tests in noise would require a much larger number of subjects with all types of hearing loss. It is hoped to carry out such an investigation at some time in the future.

## 6. Practical considerations in devising a new testing routine

a. At this stage it is worth while outlining certain practical conditions which a new testing routine should fulfil if it is to stand a reasonable chance of being considered by the Service for introduction at the Medical Boards. In brief these conditions are:—

(a) The total cost of the equipment required must be kept low. It is very doubtful whether any test would be accepted which would entail an expenditure of more than £70 for each installation.

(b) The amount of room taken up by the testing equipment should be as small as possible. In general, the premises occupied by Medical Boards are congested and most of the floor space available is likely to be in use.

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(c) It is essential that the apparatus should require very little maintenance. It should be robust and capable of functioning for long periods without adjustment. This means that the signal levels must be fixed by pre set controls and must remain reasonably constant without skilled attention.

(d) It is obviously desirable, in order to save time, to be able to test a number of candidates simultaneously. In this way 10 men, say, could pass through the examination in little more than the time required for one man, the only increase would be in the time needed to mark the extra results.

(e) It is hardly likely that the introduction of noise fields of the order of 110 db at Medical Boards would be accepted without lively protest from other departments. In order to reduce such an intense noise to a tolerable level it would have to be confined by a booth of elaborate and expensive construction. The cost alone of such a booth is sufficient to rule it out of consideration. It is evident then that we must look for a method of testing which does not require the production of intense external noise fields, but which will measure the same ability and give results which correlate closely with those of the sentence articulation test already described.

In the next paragraph a testing routine is described which appears to fulfil the conditions laid down above. It will be shown later that the results of this type of test do indeed show a significant correlation with the results of the articulation tests in external noise, and we believe that this is in every way a practicable test for use at Medical Boards.

b As a modification of the tests already described it is proposed to record the speech and the engine noise on the same gramophone disc so that both are delivered through the listener's telephones. In what follows, this particular type of test will be referred to as a "masked articulation test". The spectrum and the overall intensity of the noise at the ear drum should approximate to those of the noise inside a standard flying helmet under typical flying conditions. The ratio of the levels of the speech and noise should then be fixed so that the test is neither too easy nor too difficult. This means that the level of the speech must be much less than that delivered by the standard inter communication equipment in aircraft, otherwise the test would be too easy and the scores would tend to crowd into the upper end of the scale.

It is not pretended that the effects of a noise delivered into the telephones are in every way equivalent to those of an external noise of the same intensity at the ear drum, but if the results of the two types of test show a significant correlation we believe we are justified in adopting the second type.

Such a test has obvious advantages. The only equipment required is a turntable and pick-up, a suitable amplifier and a headset. The cost need

# b. CONSTANT SIGNAL/NOISE RATIO TEST

Experience with the "fading word test" suggested that a sound articulation test given at a constant signal/noise ratio was likely to be more satisfactory form of hearing test and this was the type of test which was tried next. A list of 68 words was selected such that the sound distribution conformed with that shown in Table II. This list was divided into two parts each containing 32 CVC words, one CV and one VC word. Each half of the test was preceded by six words, similar in character to the test words, which were not included in the marking of the test. These words were intended to give the candidate a chance to get used to the masking noise and to the testing conditions before getting to the real business of the test. In all, three complete tests were constructed, and the two parts of each test were recorded in the following manner.

TABLE I. The value of 'E' for speech sounds in external noise.

CONSONANTS		VOWELS	
Sound	% Error	Sound	% Error
f	86	u	72
p	84	a:	60
θ	76	e	57
m	75	ou	54
v	75	au	45
ð	69	o:	39
w	68	u:	39
z	64	Λ	38
s	59	i	34
d	54	ø:	33
t	53	oi	32
g	53	e	30
r	52	a	28
k	51	o	28
j	48	i:	25
l	47	ei	22
h	44	ai	19
b	42	ia	18
n	41		
ŋ	31		
dʒ	24		
tʃ	19		
ʃ	12		

TABLE II. Sound distribution in masked articulation tests.

Initial Consonants	O		Vowels	O		Final Consonants	O	
	L			L			L	
n	12		i	16		n	13	
t	10		e	10		t	11	
d	9		Λ	6		d	10	
s	8		ei	6		s	9	
l	6		ai	6		l	6	
m	5		a	3		m	5	
k	5		a:	3		k	5	
r	4		au	3		b	3	
w	4		o	3		ŋ	2	
b	3		o:	3		g	2	
			ou	3				
			u:	3				
			i:	3				

# Testing Hearing Efficiency of Aviation Candidates

## 1b Recording of test material

The masking noise was provided by the noise generating apparatus described on p 146. The output of the noise amplifier was led through an attenuator to the recording amplifier and thence to the cutter-head of

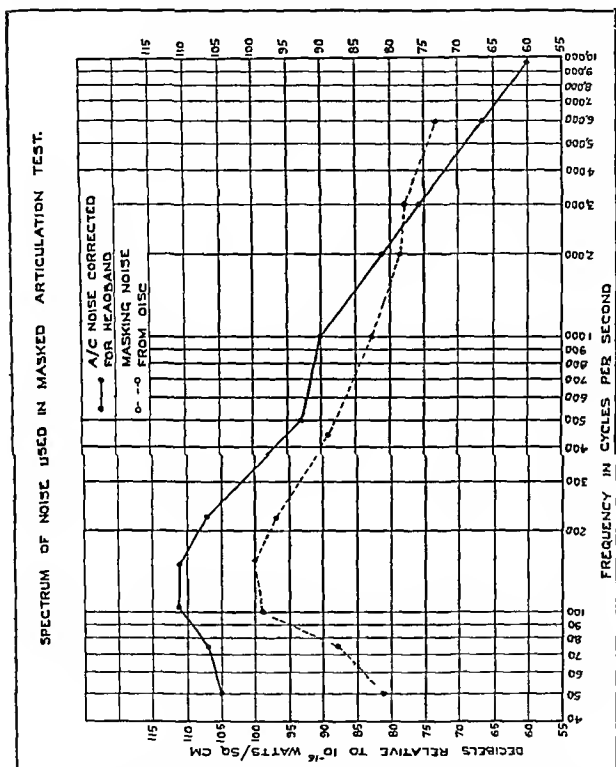


FIG 24

the recording apparatus. It was desirable that the masking noise as it arrived at the subject's ears should resemble as far as possible the noise which one hears inside a flying helmet when in the presence of actual aero-engine noise. The effect of the flying helmet is to attenuate the noise, particularly at the higher end of the spectrum and therefore when

Name	REDWIN, E.R.	Nationality	ENGLISH	Word List	S. /
No.	2089340	Articulation	81%		
1.	TALL	11. TIDE	21. -B	31. CAR	-3
2.	BORN	12. DUCK	22. TUB	32. TELL	
3.	RUDE	13. BID	23. CLOUT	33. NAME	-1
4.	KITE	14. CEASE	24. NICK	34. DEBT	
5.	SILK	15. MUST	25. LID	35. BILL	-1
6.	RAIN	16. DIN	26. DROWN	36. LESSON	
7.	MOUSE	17. COD	27. NO	37. —	-3
8.	WED	18. NUT	28. TAME	38. TEN	
9.	WIN	19. FIT	29. D—	39. RUNG	-1
10.	BOON	20. WEED	30. NIGHT	40. START	
					Correct .....

A.12,102.

FIG. 25.  
Form for hearing efficiency test.

# Testing Hearing Efficiency of Aviation Candidates

he is allowed 3 marks, since he has recorded the sounds correctly. If the test were to be used extensively for Canadian or Australian forces, for example, it would obviously be necessary to have the word lists recorded by Canadian and Australian speakers, in order to reduce the number of allowances that have to be made.

## 3b *Subjects tested*

Both the constant signal/noise ratio sound articulation test and the sentence articulation test were given to 100 subjects under standard conditions in order to estimate the degree of correlation between the two sets of results. Most of these subjects were cadets from the Aircrew Receiving Centre, but a few men who had failed to pass the whisper test at one of the Medical Boards were also included. It was noticed that most of the deaf subjects who did obtain low scores had a hearing loss of the perceptive type. On the other hand some of the highest scores were given by men who had quite a considerable degree of conductive deafness. The results of these tests are tabulated in the correlation chart, Fig. 26.

## 4b *Correlation with sentence articulation*

The correlation coefficient, calculated from the chart, has the value of 0.440. This shows that there is a significant correlation between the two sets of scores and it does appear that the second type of test is a satisfactory alternative to the test in external noise. It fulfils the general conditions laid down in section 6 and appears to be suitable for introduction in the Service. In future this test will be referred to as the hearing efficiency test.

## 8 Calibration of the Hearing Efficiency Test

One of the most difficult problems arising in the development of a test of this type is the selection of the standard score which a candidate must reach in order to pass the test. In our case we have already decided that the test must select those men who are capable of receiving radio and intercommunication messages satisfactorily under actual flying conditions. The pass mark for the test must therefore be based on the scores of a large number of fully trained operational personnel, due allowance being made for any effect which training may have on the scores as the test will be applied to untrained candidates. It is, of course, possible that some flying men are unsatisfactory as regards hearing and are retained on operational duties either because in their particular work the reception of messages is not essential, or because their ability in other directions more than compensates for any hearing defect which they may have. It has proved very difficult to get an unbiased report about each aircrew member from his flight or squadron commander, and so it has been assumed that any man who is actually engaged on

Sound, articulation.

Sentence articulation.	32-35	36-39	40-43	44-47	48-51	52-55	56-59	60-63	64-67	68-71	72-75	76-79	80-83	84-87	88-91	92-95	96-99
Sound, articulation.	32-35	36-39	40-43	44-47	48-51	52-55	56-59	60-63	64-67	68-71	72-75	76-79	80-83	84-87	88-91	92-95	96-99
32-35																	
36-39																	
40-43																	
44-47																	
48-51																	
52-55																	
56-59																	
60-63																	
64-67																	
68-71																	
72-75																	
76-79																	
80-83																	
84-87																	
88-91																	
92-95																	
96-99																	

Standard error of  
 $r = +0.440$   
 $r = +0.081$

Fig. 26.

Correlation between sentence articulation and the results of the efficiency test.

Frequency distribution of scores.

Sentence articulation.	Sound articulation.
$\bar{x}$	$\bar{y}$
32-35	52-53
36-39	54-55
40-43	56-57
44-47	58-59
48-51	60-61
52-55	62-63
56-59	64-65
60-63	66-67
64-67	68-69
68-71	70-71
72-75	72-73
76-79	74-75
80-83	76-77
84-87	78-79
88-91	80-81
92-95	82-83
96-99	84-85
	86-87
	88-89
$f$	$f$
1	1
0	0
1	0
0	0
2	0
3	2
2	4
4	3
2	2
6	12
5	9
9	13
15	18
18	7
14	9
10	7
8	5
	2
	6
	100

$\bar{x} = 80.38$

$s = \pm 13.20$

$\bar{y} = 75.94$

$s = \pm 6.62$

# Testing Hearing Efficiency of Aviation Candidates

operational flying can hear satisfactorily in noise. If a large number of cases is tested the fraction for whom this assumption is not justified is likely to be small.

## a APPARATUS USED FOR CALIBRATION

The scores for trained personnel can only be obtained by taking portable equipment to operational and training stations and testing the men whenever they happen to be off duty. A compact form of electrical gramophone and amplifier was therefore constructed, the output of the amplifier being fed into ten pairs of telephones so that ten men could be tested at once. A full description of this piece of apparatus is given in section 4 2c.

## b EFFECTS OF TRAINING ON SCORES

Before the standard for untrained personnel can be established it is essential to know by how much a man's score will vary during the course of his flying training. Some improvement might be expected as he becomes more experienced in listening in noise. It is clearly impracticable to test the same group of individuals at the beginning and at the end of their period of training as the course lasts 9-12 months, and so it was decided to take a representative group of about 100 men at each of four stages in the course and note the variation in the mean score of the groups. The four stages decided upon were (1) The Aircrew Receiving Centre where recruits are pooled immediately after being accepted for the Service. No flying is done at this stage. These men are equivalent to civilians who have passed the 20 ft whisper test. (2) The Advanced Flying Unit. Pilots who have passed through the Elementary Flying Training and Service Flying Training Schools, which are usually situated abroad, pass a few weeks on this course while waiting for vacancies at the Operational Training Units. These men have all received their wings and have had some experience in receiving messages through Gosport Tubes. A few may have been trained in planes fitted with an electrical intercommunication system. (3) The Operational Training Unit. At these units fighter and bomber aircrew personnel receive operational training in Service aircraft. The courses may last some months and only those who had been there for at least a fortnight were included in the test group. (4) Operational aircrew.

It was noticed that at the O T U and operational stages a considerable number of Dominion and foreign personnel were amongst those tested. Their results were later eliminated as it was felt that they might possibly have some difficulty with the accent of the announcer.

A number of aircrew wireless operators under training were also tested at one of the signals schools and their results are added for comparison.



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The results of all the tests are tabulated below.

<i>Stage</i>		<i>Number tested</i>	<i>Mean score</i>	<i>Standard deviation</i>
A.C.R.C.		196	76.51	$\pm 6.94$
A.F.U.		189	79.26	$\pm 6.42$
O.T.U.	(a)	329	77.21	$\pm 7.19$
"	(b)	229	78.93	$\pm 6.00$
Operational	(a)	143	74.10	$\pm 8.86$
"	(b)	73	76.32	$\pm 7.09$
Signals School		98	75.52	$\pm 7.38$

The suffix (b) refers to the results for subjects from the British Isles only. It can be seen that the mean scores for these subjects are slightly higher than for the corresponding unrestricted group. The standard deviations are also slightly less, largely owing to the removal of some of the stragglers at the lower end of the frequency distribution.

Two reasons may be advanced to explain the rise and subsequent fall in the mean scores. At both the A.C.R.C. and the A.F.U. stages the trainees were very keen to co-operate as fully as possible. They were probably under the impression that the results of the test would in some way affect their future. The rise in score can therefore be attributed to the effect of experience, although most of the subjects had up to that point used only Gosport Tubes. At the O.T.U.'s and operational stations this keenness was not so marked. Although willing enough to try the test some of the men took it rather light-heartedly and their concentration may not have been so intense. This could account for the fall in the scores at these stages. At the same time it is quite possible that an increased number of flying hours in noisy Service aircraft does in fact impair the hearing efficiency to a certain extent. The loss produced by exposure to noise is of the perceptive type which we know from previous experience in testing deaf subjects is more likely to cause a low score on this test than a comparable loss of the conductive type.

The general conclusion to be drawn from these results is that on the average the score of a fully trained man is not likely to be appreciably greater than that of a completely untrained candidate. This conclusion is supported by the results of subsequent tests on a much larger number of subjects, described in sections 8.c and 8.d.

## c. PERFORMANCE OF OPERATIONAL PERSONNEL

It has been said that the pass mark for the test must be based on the results of fully trained operational personnel. The gramophone audiometer was therefore taken to Fighter and Bomber Command operational stations and the test given to 700 aircrew members, 117 from Fighter Command and 583 from Bomber Command.

Each man was told before attempting the test that the results would

# Testing Hearing Efficiency of Aviation Candidates

not affect him personally, but it was pointed out to him that he was helping to set the standard for a new Service hearing test and that lack of concentration on his part would make the results quite useless. In every case the co-operation was very satisfactory. The frequency distribution

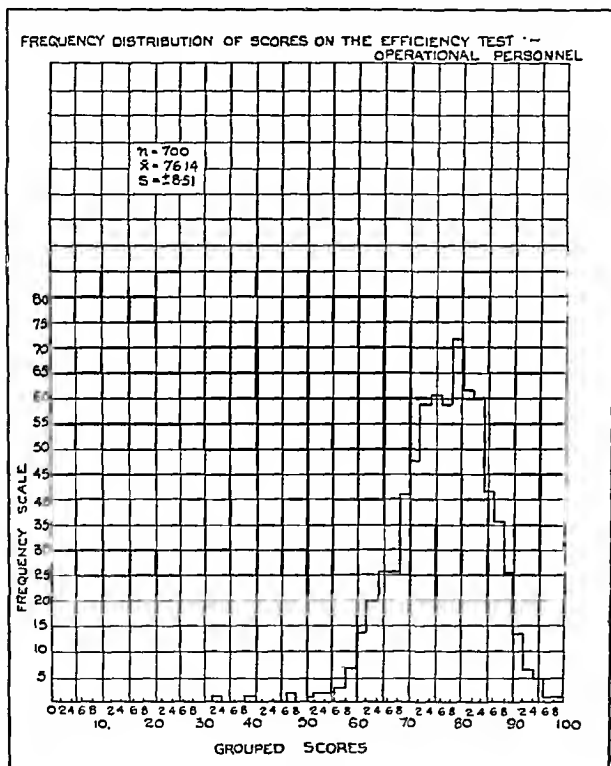


FIG. 27.

of the aircrew scores is shown in Fig 27. Assuming that all personnel engaged in operational flying can hear satisfactorily in noise, we should be compelled to set the pass mark at least not higher than the lowest score obtained by the operational personnel. This would, however,

give an impossibly low pass mark and as the correlation between the results of the efficiency test and the ability to receive connected speech in noise is not complete, it is better to set a provisional pass mark at some reasonable figure which only a small proportion of the operational personnel fail to reach. For example, with a pass mark of 60 per cent. only 2.7 per cent. of these subjects fail to reach the standard. This does not appear an unduly high proportion in view of the assumptions that have been made, and this value might well be adopted as the provisional pass mark. The validity of this standard can be established by noting the number of aircrew who are lowered in medical category when the test has been in operation for some time. With the present test this number is small and it would appear therefore that few candidates are admitted who cannot carry out their duties efficiently. An increase in the number of men who have to be degraded later would mean that the new test is admitting unsuitable candidates and the pass mark would have to be raised. It will be seen later (section 8.d) that a pass mark of 60 per cent. will probably produce a rejection rate which compares favourably with that of the present test.

### d. COMPARISON WITH THE PRESENT TEST

It is important to know whether this new hearing test will let through more candidates than the standard whisper test. In order to compare the two tests our portable testing equipment was installed at one of the Aviation Candidates Medical Boards, and every man passing through the board was given both tests. This was continued until data had been collected on 1,000 men.

The number of candidates who failed to hear forced whisper at 20 ft. and so were rejected for all forms of flying duties was 39, i.e. 3.9 per cent. From the frequency distribution of the scores on the efficiency test, Fig. 28, it can be seen that in order to fail the same percentage of men as the whisper test the pass mark would have to be set at 62 per cent. The number of candidates whose scores fell below our proposed pass mark of 60 per cent. was 23. That is to say, with this standard the number of failures is reduced by approximately 40 per cent.

In order to compare the results of the untrained and fully trained personnel it is necessary to exclude from the former the scores obtained by candidates who fail the whisper test as all the operational personnel have at some time passed this test. Fig. 29 shows the frequency distribution of the first 700 A.C.M.B. candidates who passed the whisper test. It can be seen at once that the distribution is very similar to that of the fully trained personnel, see Fig. 27. The difference between the two means is only 0.2 per cent. which bears out our previous conclusion (p. 182) that the score obtained by a fully trained man is not likely to be appreciably greater than that of an untrained candidate.

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It is interesting to note that the candidates who failed the whisper test were in almost all cases not those who failed the efficiency test. In fact out of the 23 who scored less than 60 per cent only two failed to pass the whisper test. Out of the remaining 21, 7 were rejected for flying

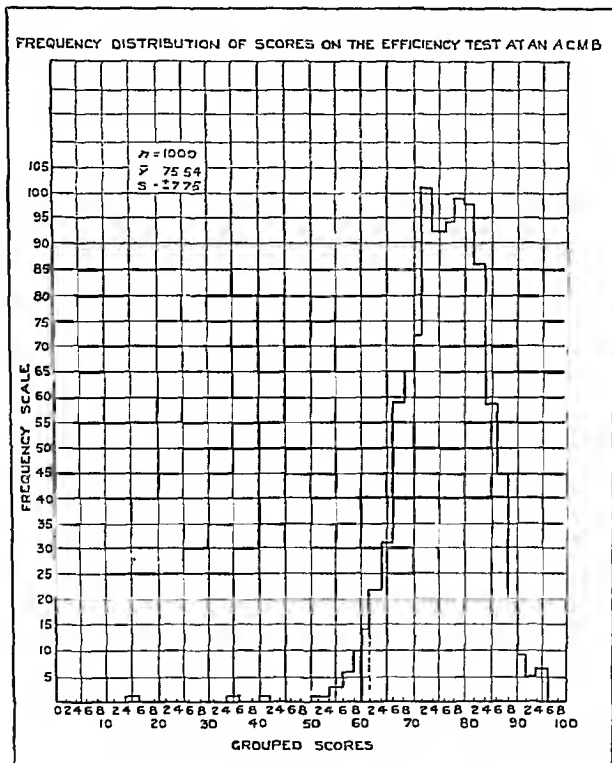


FIG 28

duties on other grounds. The other 14 who entered the Service will be kept under observation during training in order to find out whether they do in fact have difficulty in listening in noise.

It was noticed that quite a number of candidates who failed the whisper

test obtained remarkably high scores on the efficiency test. Most of these had some degree of conductive deafness as indicated by tuning fork tests.

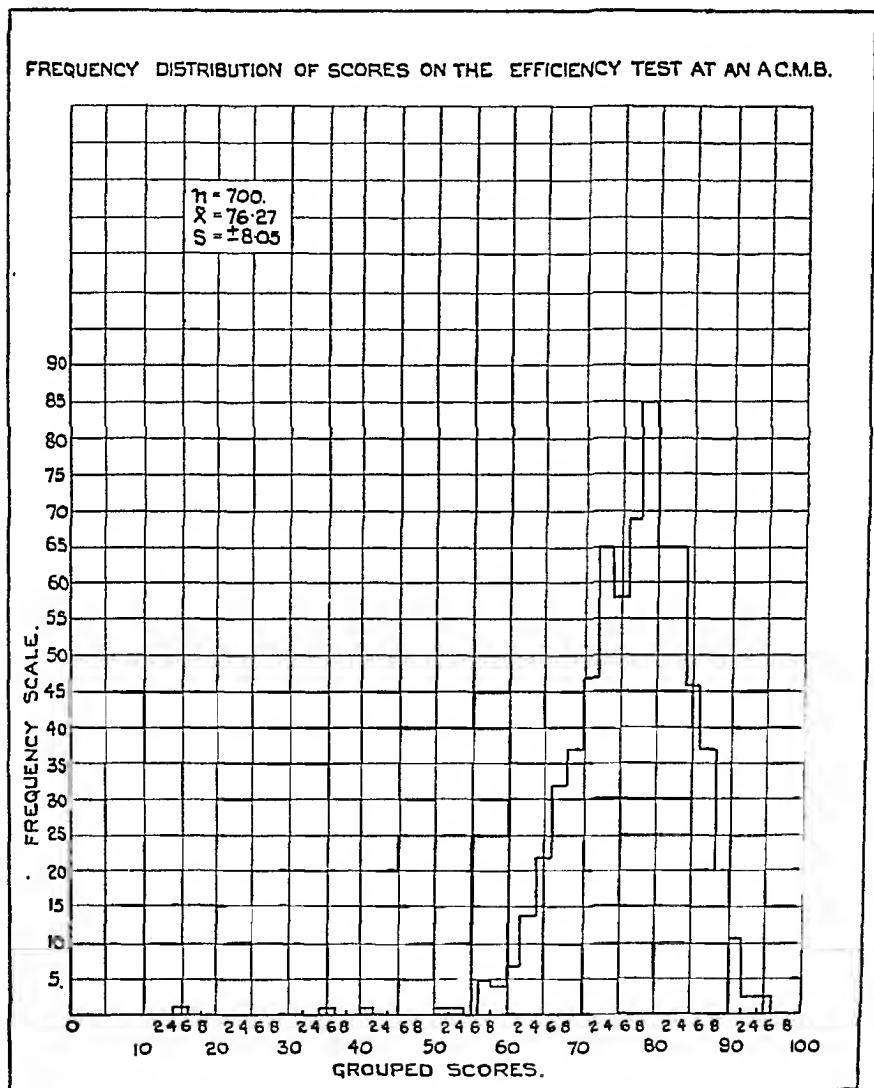


FIG. 29.

#### e. RELIABILITY OF RESULTS

At this stage a short series of tests was carried out to measure the reliability of the efficiency test and the difference in intrinsic difficulty between the alternative word lists, A, B and C, and also to get an estimate

# Testing Hearing Efficiency of Aviation Candidates

of the number of times a disc can be played without appreciable deterioration

By reliability is understood the probability of obtaining closely similar scores when the test is given twice to the same subject. A simple way of estimating this probability is to determine the correlation coefficient for first and second attempt scores.

All these tests were carried out at the Aircrew Receiving Centre. Forty cadets were allowed two attempts at the efficiency test and it was noted in most cases that the scores were higher at the second attempt. It is very unlikely that memory can affect the results of a test of this length and consequently the increase in the scores is due to practice in listening under these conditions. The two sets of scores obtained are shown in Table III. The product moment correlation coefficient, calculated in the usual way, is equal to 0.943. This value is sufficiently high for us to be able to say that the test is highly reliable.

TABLE III Difference between 1st and 2nd attempt scores on efficiency test

1st attempt $X$	2nd attempt $Y$	$(Y-X)$	1st attempt $X$	2nd attempt $Y$	$(Y-X)$
73	78	5	73	77	4
49	56	7	75	74	-1
69	74	5	82	83	1
68	72	4	75	77	2
54	64	10	76	85	9
68	72	4	74	76	2
61	69	8	70	78	8
63	67	4	59	61	2
62	58	-4	88	90	2
69	69	0	82	83	1
81	80	-1	73	73	0
75	73	-2	68	76	8
75	78	3	76	79	3
70	76	6	68	69	1
55	59	4	75	83	8
86	85	-1	63	66	3
73	75	2	84	88	4
80	86	6	57	60	3
64	71	7	79	80	1
82	83	1	85	86	1

Mean value of  $(Y-X) = 3.25$

Standard error of  $(Y-X) = \pm 0.505$

From these two sets of scores we are also able to obtain an estimate of the "practice effect" that is to say the improvement to be expected at a second attempt. This effect is assumed to be equal to the mean difference between the scores of the 40 cadets. The mean difference for the 40 subjects is 3.3 and the standard error of this mean is  $\pm 0.51$ . We can therefore, take 3 units as the probable increase on retest. This is admittedly only a rough estimate of the practice effect, but it serves to show that scores on retest are likely to be only slightly greater than those on the first attempt. On the assumption that memory effects play

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- (2) The total number of pips in each group to vary from 2 to 5.
- (3) The duration of the pips to be as constant as possible and equal to the pause between pips.
- (4) The total duration of all the groups to be the same, so that a group containing less than 5 pips will contain silent periods. This means that all groups will not be given with the same rhythm and there will be less chance of a candidate's guessing the right answer through hearing part of a group.
- (5) The recording level must be so adjusted that when the disc is played back through the efficiency test equipment and received in one ear only the loudness of the pips is judged to be the same as that of the signal from the Western Electric audiometer set at the corresponding frequency and intensity.
- (6) Each group of pips to be announced by number, the level of voice remaining constant throughout the test.
- (7) Two complete discs to be recorded with different arrangements of pips in the groups, so that both ears can be tested separately without the subject being helped by memory.

TABLE IV. Arrangement of ' pips ' in pure tone test.

Frequency in C.P.S.	Db. above Threshold	Group Number	Arrangement of ' Pips '				
4000	60	1	—	—			
"	"	2	—	—	—		
"	"	3	—		—		
"	40	4	—			—	
"	"	5	—	—	—	—	—
"	"	6	—		—		
"	20	7	—	—	—	—	—
"	"	8	—		—		
"	"	9	—	—	—	—	
2000	60	10	—	—	—		
"	"	11	—		—		
"	"	12	—	—			
"	40	13	—	—	—		—
"	"	14	—	—			
"	"	15	—		—	—	
"	20	16	—	—	—	—	—
"	"	17	—	—	—		
"	"	18	—		—		
1000	60	19	—	—		—	—
"	"	20	—	—	—		
"	"	21	—	—	—		
"	40	22	—		—		
"	"	23	—	—	—	—	
"	"	24	—	—	—	—	—
"	20	25	—		—	—	
"	"	26	—	—			
"	"	27	—	—	—	—	
250	60	28	—		—	—	
"	"	29	—	—			
"	"	30	—	—	—		
"	30	31	—		—	—	
"	"	32	—	—	—	—	
"	"	33	—	—	—	—	—

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A typical arrangement of the pips is shown diagrammatically in Table IV where each bar represents one pip. It will be seen that the total duration of the group is shorter at each of the 60 db levels. This enables us to get the whole test on one side of a 12 in. disc without unduly rushing the pips. The 60 db level was considered to be the least critical as the number of candidates having a hearing loss as great as this is not likely to be very large. It was found that a tone of 250 c.p.s. 20 db above threshold was almost completely masked by the small amount of mains hum getting through to the telephones and so it was decided to have only two levels at this frequency, one at 60 db and the other at 30 db above threshold.

## b RECORDING OF THE PURE TONE TEST

The discs were recorded using the channel described in section 3 b. The pure tones were obtained from the B.S.R. oscillator and fed through the attenuators to the recording amplifier. A Morse tapping key was inserted between the oscillator and the attenuators so that the signal could be interrupted at will. The connections to the key were so arranged that each time the output circuit was broken a dummy load was connected across the output of the oscillator so keeping the voltage fairly constant. In selecting the attenuator settings continuous bands of each pure tone were recorded and replayed through the gramophone audiometer. These recorded tones were listened to with one ear and the loudness of each tone was compared subjectively with that of the signal from the Western Electric audiometer at the required frequency and intensity, received in the other ear. A series of subjective judgments was needed in order to determine the attenuator settings in the recording channel which would give the required sensation levels on replay. When these settings had been determined provision was made for injecting speech signals into the channel so that the group numbers and the opening and closing announcements could be recorded.

The complete recording channel is shown schematically in Fig. 30. When the microphone was in use the attenuators were removed from the circuit by means of the switch S.

The two tests were recorded and pressings from the master records were used in a series of tests to determine how closely the results agree with pure tone audiometry.

## c TECHNIQUE AND MARKING OF TEST

The subject wears the headband and receivers used in the efficiency test, but the signal is sent to only one ear at a time. He is provided with the form shown in Fig. 31 on which he is asked to record his name and the ear in which the signal is received. It is explained to him that he will hear a series of groups of pips of varying pitch and loudness, each group



and threshold is recorded as 15 db. and hearing loss between 60 db. and 30 db. as 45 db. A glance at Fig. 31 will make this method of recording the results quite clear.

It must be emphasized that this test cannot measure hearing loss to a greater accuracy than  $\pm 10$  db., and that a result which is expressed as 30 db. simply means that the hearing loss for that frequency lies somewhere between 40 db. and 20 db.

#### d. GRADING OF CANDIDATES BY THE DIAGNOSTIC TEST

It has been said above that a candidate who passes the efficiency test is to be considered fit for some form of flying duties. It is proposed to divide all candidates who pass the test into two categories on the basis of their hearing loss. Category A will include men fit for aircrew duties requiring the highest degree of auditory acuity and reliability. What these duties are would be decided upon in consultation with the Signals and General Duties branches of the R.A.F. They would probably include, for example, the duties of Fighter pilot and wireless operator since these men have ultimate responsibility for the reception of radio signals in their aircraft and the safety of others may well depend on their hearing efficiency. 20 db. has been fixed as the greatest hearing loss permissible at any frequency for admission to category A; that is to say, a candidate will be placed in category A only if the result of his diagnostic test reads 10 db., 10 db., 10 db., 15 db., for each ear. Candidates who fail to reach this standard in the pure tone test will be placed in category B.

#### e. COMPARISON OF RESULTS WITH PURE TONE AUDIOMETRY

To determine the validity of the diagnostic test it is necessary to compare its results with those of pure tone audiometry on a large number of cases with varying types of threshold curve. This comparison can be made by grading candidates on both pure tone audiometry and the diagnostic test. The first hundred cases which have been treated in this way have shown that the agreement between these two methods of grading is not sufficiently close to justify the adoption of the diagnostic test in its present form, as 9 per cent. of the cases were wrongly graded. It must be remembered that the grading with the diagnostic test depends on the reception of the 20 db. level at each frequency. The results at this level are likely to be unreliable owing to the masking effect of needle scratch and any sudden extraneous noise. If the number of groups given at this level is increased it is probable that the results will become more stable and the grading on the new test may be more satisfactory. We therefore propose to record another version of the test with a greater number of groups at the 20 db. level and a report on this new test will be given later.

# Testing Hearing Efficiency of Aviation Candidates

candidate cannot hear a particular level because he failed to record the group correctly.

For convenience in presenting the results of the test the following convention has been adopted. If a subject receives the 20 db. level

Name..*E.A.R.H.E.A.R.T.*..... No...*2174390*.....

.....*LEFT*.....Ear.

1. *II* ✓ 10. *III* ✓ 19. *IIII* ✓ 28. *III* ✓

2. *III* ✓ 11. *II* ✓ 20. *III* ✓ 29. *II* ✓

3. *II* ✓ 12. *II* ✓ 21. *III* ✓ 30. *III* ✓

4. *IIII* X 13. *IIII* ✓ 22. *II* ✓ 31. *IIII* ✓

5. *IIII* ✓ 14. *II* ✓ 23. *IIII* ✓ 32. *III* ✓

6. *III* X 15. *II* X 24. *IIII* ✓ 33. *IIII* X

7. *III* X 16. X 25. *III* ✓

8. *II* X 17. *I* X 26. *II* ✓

9. *I* X 18. X 27. *II* X

Frequency·	4000	2000	1000	200
Hearing Loss:	<i>50</i>	<i>30</i>	<i>10</i>	<i>15</i>

*A10778.*

FIG 31  
Form for pure tone test

correctly his hearing loss is recorded as 10 db , if he receives 40 db but not 20 db it is recorded as 30 db , if he receives 60 db but not 40 db it is recorded as 50 db This applies to 4000, 2000, and 1000 cps As there are only two levels for 250 cps hearing loss between 30 db

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and threshold is recorded as 15 db. and hearing loss between 60 db. and 30 db. as 45 db. A glance at Fig. 31 will make this method of recording the results quite clear.

It must be emphasized that this test cannot measure hearing loss to a greater accuracy than  $\pm 10$  db., and that a result which is expressed as 30 db. simply means that the hearing loss for that frequency lies somewhere between 40 db. and 20 db.

### d. GRADING OF CANDIDATES BY THE DIAGNOSTIC TEST

It has been said above that a candidate who passes the efficiency test is to be considered fit for some form of flying duties. It is proposed to divide all candidates who pass the test into two categories on the basis of their hearing loss. Category A will include men fit for aircrew duties requiring the highest degree of auditory acuity and reliability. What these duties are would be decided upon in consultation with the Signals and General Duties branches of the R.A.F. They would probably include, for example, the duties of Fighter pilot and wireless operator since these men have ultimate responsibility for the reception of radio signals in their aircraft and the safety of others may well depend on their hearing efficiency. 20 db. has been fixed as the greatest hearing loss permissible at any frequency for admission to category A; that is to say, a candidate will be placed in category A only if the result of his diagnostic test reads 10 db., 10 db., 10 db., 15 db., for each ear. Candidates who fail to reach this standard in the pure tone test will be placed in category B.

### e. COMPARISON OF RESULTS WITH PURE TONE AUDIOMETRY

To determine the validity of the diagnostic test it is necessary to compare its results with those of pure tone audiometry on a large number of cases with varying types of threshold curve. This comparison can be made by grading candidates on both pure tone audiometry and the diagnostic test. The first hundred cases which have been treated in this way have shown that the agreement between these two methods of grading is not sufficiently close to justify the adoption of the diagnostic test in its present form, as 9 per cent. of the cases were wrongly graded. It must be remembered that the grading with the diagnostic test depends on the reception of the 20 db. level at each frequency. The results at this level are likely to be unreliable owing to the masking effect of needle scratch and any sudden extraneous noise. If the number of groups given at this level is increased it is probable that the results will become more stable and the grading on the new test may be more satisfactory. We therefore propose to record another version of the test with a greater number of groups at the 20 db. level and a report on this new test will be given later.

# Testing Hearing Efficiency of Aviation Candidates

## 10. Application of the New Test

### a PERSONNEL TO BE TESTED

It is proposed that this new hearing test should replace the 20 ft forced whisper test at the Aviation Candidates Medical Boards. It will therefore be given to all candidates for flying duties in the Royal Air Force. It will also be given to flying personnel at invaliding and commissioning boards and to cases sent to the Consultant in Oto-rhino-laryngology for assessment. It is estimated that about 14 complete sets of testing equipment will be required to carry out this programme.

### b DESCRIPTION OF COMPLETE TEST

It may be as well at this stage to describe the whole process of testing an aviation candidate under the new scheme and to recapitulate the information which would be handed to the examining specialist as a result of the test.

The candidate would first do the efficiency test, i.e. would hear the complete articulation test delivered to both ears, and would write down his responses. These would be handed in for correction and he would go on immediately to the pure tone test, given first to one ear and then to the other. He would then proceed to some other part of his medical examination whilst the correction of his responses to both tests was completed. If his score for the efficiency test were below the required standard he would be rejected for aircrew and would proceed no further with the medical examination. All candidates who reach the required standard in the efficiency test would be sent on to the Ear, Nose and Throat specialist who would receive also the results of the candidates' pure tone test. The latter will give him the following information about each candidate —Whether he has in either ear a hearing loss for any of the frequencies 250, 1000, 2000, 4000 c.p.s., and whether such hearing loss is between 0 and 20 db, between 20 and 40 db, between 40 and 60 db, or greater than 60 db. The specialist will decide whether there is any clinical reason for rejecting the candidate in spite of his having passed the efficiency test, and if there is none, he will accept the candidate for flying duties and record his category (see section 9 d).

### c TRAINING OF OPERATORS AND MAINTENANCE OF EQUIPMENT

It will be evident that the carrying out of the two tests can scarcely be undertaken by the Ear, Nose and Throat specialist himself since a considerable amount of work will be involved in the marking of the responses to the test and in the operation of the equipment. It will therefore be necessary to provide operators who will undertake these duties. Probably W.A.A.F. personnel, if specially selected, will be most suitable for this purpose. The operators would need some period of training, more particularly in the marking of the responses, since it is essential that the

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marking should be done in as uniform a manner as possible. It is also desirable that the operator should have at least some knowledge of the objects and of the technical basis of the test.

In order to mark the articulation tests, the operator will need first to acquire the ability to distinguish pronunciation from spelling. This will be achieved by means of elementary instruction in the phonetics of English and by extensive practice in the marking of sample test responses. The instruction will include some reference to various pronunciations of English (Canadian, Australian, etc.), in so far as they are liable to affect the marking of the test. In addition to this kind of instruction and practice it will be well for the operators to have some very elementary knowledge of the hearing mechanism, of sound and its reproduction, and of the simplest of statistical techniques. Further, they will need to be familiar with the equipment used and to be capable of making any necessary minor adjustments. For example, they would be expected to carry out the process of calibration referred to in section 4.2c, p. 157.

The testing equipment has been designed to be as free from faults as possible and maintenance of the apparatus should not present any very serious problem. A technician will probably be needed to travel from one medical board to another to see that the apparatus is working as it should and to be on call to deal with any serious breakdowns. Less serious faults, such as defective leads or external connections, could be dealt with by any electrical mechanic who is available at the medical board.

## d. ADMINISTRATION

The application of the new test will involve a certain amount of additional administrative work. There will be, for example, the provision and training of operators for the test. It is estimated at present that two operators per medical board will be required and these would share the duties of operating the audiometer and of marking the responses. For some considerable period it will be necessary to have the results of all tests collected at some centre where they can be analysed so that a check can be kept on the working of the test and particularly on the rejection rate. It will be necessary also to collect information concerning the incidence of hearing disability among the personnel selected by means of the new test in order to see whether the test does in fact admit only candidates who are capable and who remain capable of performing aircrew duties.

The inspection of the results from various medical boards will help to act as a check on the performance of the apparatus as consistently high or consistently low results from one board may be an indication that the calibration of the equipment is not being properly carried out or that some part of the apparatus is showing unexpected variation.

The pass mark for the efficiency test which is set when the test first

# Testing Hearing Efficiency of Aviation Candidates

goes into operation will naturally be provisional and may be changed after some month's experience with the test. Such a change would be communicated to the operators at the various boards. A central organization would also be responsible for the supply of discs, replay needles and spares for the audiometers in use and for any technical assistance that was required.

## Appendix I

The following table gives the phonetic symbols used in this report for the transcription of pronunciation. The pronunciation of the key words should be understood to be that of a Southern English speaker. Whenever phonetic symbols occur in the text they are underlined.

<i>Phonetic Symbol</i>	<i>Keyword</i>	<i>Phonetic Symbol</i>	<i>Keyword</i>
p	pie	i	beat
b	buy	ɪ	bit
t	tie	e	bet
d	die	æ	bat
k	car	ɑ	bar
g	guy	o	cot
tʃ	church	ɒ	bought
dʒ	judge	u	cook
f	foe	u	boot
v	vie	ʌ	but
θ	thigh	ə	bird
ð	thy	ə	china
s	sight	eɪ	bait
z	zebra	ou	boat
ʃ	shy	aɪ	bite
ʒ	measure	au	bout
h	high	ɔɪ	boy
m	my	ɪə	beer
n	nigh	eə	bear
ŋ	sing	uə	cure
l	lie		
r	rye		
j	yawn		
w	why		

## Appendix II

### SPECIMEN ARTICULATION TESTS

- 1 The woman sat in the park
- 2 The boy did his homework
- 3 The players deal the cards
- 4 The girl gets a prize
- 5 Sailors part from their wives
- 6 Carpenters use a chisel
- 7 The servant dropped the plate.

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- 8 The artist draws a sketch.
- 9 The crowd looked at the queen.
- 10 The stranger asked the shortest way.
- 11 The furniture was moved in a van.
- 12 The fat child cut her thumb.
- 13 Schoolchildren learn lessons.
- 14 The baker had some more bread.
- 15 The labourer loads the lorry.
- 16 Darkness frightens little children.
- 17 The housekeeper bought the food.
- 18 Hens have chicks in the spring.
- 19 The shepherd found the lamb.
- 20 The younger son joined the air force.
- 21 The crowd jeered at the speaker.
- 22 The maid took care of the clothes.
- 23 The bright sun thawed the snow.
- 24 The shopkeeper shows his goods.
- 25 The infant screamed with rage.

## WORD TEST

Scratch	Beard	Job
Mouse	Gate	Chief
Time	Thief	Shawl
Desk	Noon	Fox
Ring	Rush	Road
Yard	Fright	Voice
Pet	Ford	Tart
Wool	Cares	Cat
Herd		

## CONSONANT TEST

Pie	My	Which
Thy	Wick	Whizz
Wing	Die	Tie
Nigh	Wig	Whim
Will	Win	Fie
By	Lie	Thigh
Wry	Vie	Whip
Whiff	Wish	High
Why	Sigh	Wit
With	Guy	Shy

## VOWEL TEST

Bit	Bait	But
Beat	Bought	Bat
Boat	Bite	Bet
Bout	Boot	Boat
Bet	Bite	But
Bait	Boot	Bat
Beat	Bought	Bit

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## EFFICIENCY TEST

Part I		Part II	
1 Tall	21 Cab	1 Sail	21 Coat
2 Torn	22 Tub	2 Mine	22 Tongue
3 Root	23 Out	3 Take	23 Sin
4 Kite	24 Nick	4 Cot	24 Legs
5 Sill	25 Lid	5 Dumb	25 Nail
6 Rain	26 Down	6 Big	26 Tan
7 Mouse	27 Know	7 Dawn	27 Doubt
8 Red	28 Tame	8 Web	28 Suit
9 Win	29 Dine	9 Tea	29 Loss
10 Noon	30 Night	10 Corn	30 Card
11 Tide	31 Warm	11 Ice	31 Net
12 Duck	32 Tell	12 Noon	32 Dead
13 Bib	33 Lame	13 Bus	33 Mate
14 Cease	34 Debt	14 Tile	34 Limb
15 Moss	35 Till	15 Nick	35 Null
16 Din	36 Less	16 Mud	36 Knit
17 Cud	37 Nail	17 Nag	37 Tin
18 Nut	38 Ten	18 Barn	38 Debt
19 Sit	39 Rang	19 Miss	39 Nice
20 Weed	40 Tart	20 Wreck	40 Did

## 11. Revised version of the Pure Tone Test

In section 9 a description is given of the diagnostic test which was designed to enable a rough estimate to be made of an aviation candidate's acuity of hearing. It is said there that such a test serves as an aid to the diagnosis of aural disease and also makes it possible to assess deterioration in a man's hearing during his service career. In view of the shortage of trained flying personnel at the time when this hearing test was developed it was proposed to accept for training all candidates who could pass the efficiency test and subsequently to grade them on the basis of their hearing loss as shown by results of the pure tone test. For those duties which require a high degree of auditory acuity, e.g. wireless operator, candidates would require to have a normal threshold of hearing throughout the frequency range. All other candidates who were able to pass the efficiency test but who did not have a normal threshold would be assigned to flying duties where the reception of speech signals only is required.

In the later stages of the war the decision was made to accept for training for all flying duties only those candidates who have an effectively normal threshold of hearing in quiet and can hear speech satisfactorily in noisy surroundings. 20 db has been fixed as the greatest threshold hearing loss which a man can have at any frequency and still be counted normal. A new version of the pure tone test has therefore been



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constructed which will pick out those candidates who have normal hearing in quiet and it is hoped will prove more reliable in use than the version described in section 9.

The efficiency test and this new version of the pure tone test have recently been accepted as the standard test of hearing for all candidates for flying duties with the Royal Air Force and the two tests are now given to the candidates who pass through the only Aviation Candidates Medical Board which is at present functioning.

## a. CONSTRUCTION OF THE TEST

This new version of the test has been designed so that it can be given through the R.A.F. Gramophone Audiometer. One of the difficulties encountered in using the old pure tone test described in section 9 was the partial masking of the 20 db. signal by the background noise of the disc. This background noise increases with the number of playings of the disc and it becomes progressively more difficult to hear the 20 db. set of pips.

In order to overcome this masking the new disc was recorded at a high intensity level and a gain control was inserted in the amplifier of the audiometer so that the intensity of the output signal could be cut down to the required level. By this means a much better signal to noise ratio can be achieved as the background noise is attenuated with the signal.

As it has been decided to reject all candidates who have a hearing loss greater than 20 db. above threshold at any frequency it is necessary to have a 20 db. level of test signal only and to reject those candidates who do not respond satisfactorily at this level. With this arrangement it is possible to record a much larger number of the 20 db. level test signals and it is to be expected that the agreement of the results with those of pure tone audiometry would show an improvement.

It was decided to retain the form of the original pure tone test to a considerable extent and to record pure tones of the five frequencies 4000, 2000, 1000, 500 and 250 c.p.s. in groups of "pips" at a level which would give results corresponding to those obtained using the Western Electric 6B audiometer at a setting of 20 db. above threshold.

The following scheme for the construction of the test discs was adopted. Three sets of pips were recorded at each frequency. These sets were subdivided into three groups, each of which contained either three or four individual pips. A typical arrangement of the groups of pips is shown in Table V.

Each set of three groups of pips is announced by a number and opening and closing announcements are made on the disc so that the candidate knows when the test begins and ends. The intensity level of the speech is well above that of the pure tones so that it can be heard by all except the very deaf candidates.

Two discs were recorded with a different sequence of pips on each so

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that both ears of the candidate could be tested without this response on the second test being helped by memory

## b RECORDING OF THE TEST

The discs were recorded using the channel shown in Fig 30 with one small modification. An automatic switch was inserted in the line in place of the Morse key so that the signal could be interrupted at a constant rate. This automatic switch consisted of an ordinary recording blank from the surface of which segments of the paint had been removed. The disc was rotated by a slow speed electric motor and a wiping contact on the surface of the disc short circuited the output of the oscillator when it passed over the bare metal segments. When the wiping arm passed over the painted segments the signal was allowed to pass through the attenuating network to the cutter head. An additional manually operated switch was connected in parallel with the automatic switch so that the steadily interrupted signal could be broken up into groups of any desired number of pips.

The opening and closing announcements and the number preceding each set of three groups were recorded through the microphone and speech channel shown in Fig 30. When the speech was being recorded the key (S) was opened so that the attenuator was taken out of circuit. This key was closed again before recording the pure tone signals.

The speech was recorded at as high an intensity level as possible without introducing too much distortion in the recording. It was then possible to record the pure tone signals at a reasonably high level of intensity and yet to have the speech considerably louder than the pips when their intensity is reduced to the 20 db level.

When selecting the attenuator settings for recording the pure tones continuous bands of each frequency were recorded and played back through the Gramophone Audiometer modified according to the method described in the next section so that the intensity of the signal coming from the earpiece was reduced to a level of approximately 20 db above threshold. The bands of pure tones were then listened to with one ear and the loudness of each pure tone compared with that of the corresponding frequency from the Western Electric Audiometer set at 20 db above threshold. When it was found that the two signals were not equally loud the intensity control of the Western Electric Audiometer was adjusted to give a balance and the amount by which it had to be changed was applied as a correction to the attenuator setting in the recording channel. This procedure was repeated using a number of trained observers until a satisfactory result was obtained.

When agreement was reached on the attenuator settings the test was recorded on the standard M S S supercut recording blanks and these discs were sent to the Decca Recording Company for processing.

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## c. MODIFICATION OF THE GRAMOPHONE AUDIOMETER

In order to play these pure tone discs through the Gramophone Audiometer it is necessary to modify the amplifier so that the intensity of the signal is reduced to the required level.

At first it was thought that the initial set of pips at each frequency should be given at a level of 30 db. above threshold in order to accustom the candidate to the listening conditions, and that the intensity should then be reduced to 20 db. above threshold for the two remaining sets. This was done by introducing a three position potentiometer, controlled by a switch on the top plate of the audiometer, into the grid circuit of the output valve. In the first position, used with the efficiency test, the level of the output signal was not affected. In the other two positions values of the grid resistance were selected which reduced the intensity of the pure tone pips to levels corresponding to 30 db. and 20 db. above threshold.

It was found later that the provision of this 30 db. level did not improve the agreement between the test and individual pure tone audiometry and as it imposes a considerable strain on the test operators to have to remember to change the switch setting at the correct moments during the test it was decided to have a two position switch only, one position for the efficiency test and one for the 20 db. level pure tone test. In order to reduce the number of extra controls on the audiometer the circuit was modified slightly and the resistances were mounted on the 3-position key used in calibrating the machine. When this key is depressed it is in the calibration position, when it is horizontal the efficiency test can be given at the normal level, and when it is raised the pure tone test can be given at a level of 20 db. above threshold.

## d. COMPARISON OF RESULTS OF THE TEST WITH PURE TONE AUDIOMETRY

In order to validate this test it is necessary to compare its results with those of individual pure tone audiometry. This is done by giving both tests to a fairly large number of unselected subjects. The comparison is then made by setting a pass mark of 20 db. on the audiogram and stating that a candidate who has a hearing loss greater than 20 db. in either ear at one or more of the frequencies 4000, 2000, 1000, 500 and 250 c.p.s. fails on pure tone audiometry. It is possible to vary the method of marking the pure tone test and it was decided to adopt whichever method gave the best agreement with the pure tone audiometry.

A large number of subjects were tested at an Aviation Candidates Medical Board and in the Department of Otorhinolaryngology at the Central Medical Establishment. Most of the cases tested at the Aviation Candidates Medical Board had normal hearing and so passed both tests, but more than half the cases at Central Medical Establishment failed at one or more frequencies. Several different methods of marking the pure

# Testing Hearing Efficiency of Aviation Candidates

tone test results were investigated and it was found that the following method gave best agreement with audiometry. The first set of three groups at each frequency is given for practice only and is not marked. The candidate must then get two groups correct out of each of the remaining two sets at each frequency in order to pass. If he fails at any frequency he is considered to have failed the complete test. In all 545 results were marked in this way and it was found that 5.7 per cent of the subjects were placed in different categories by the two tests. This agreement is quite good, in fact it is somewhat better than the agreement obtained between test and retest on the same subjects using pure tone audiometry alone.

## 12 Description of the Complete Hearing Test

A brief description will now be given of the complete hearing test as it should be carried out at the Aviation Candidates Medical Board.

The candidate is first given the efficiency test in both ears together. His responses are handed in for marking and he goes on immediately to the pure tone test, given first to one ear and then to the other. If he fails at one or more frequencies he is retested, using a different headset in order to avoid the possibility of failing owing to a defect in the earpiece. There is always a chance that a candidate may fail at one frequency because of a sudden extraneous noise or other distraction and so the rule was adopted that all candidates who fail are to be retested and are rejected only if they fail at the second attempt.

The test operators enter the results of both the efficiency test and the pure tone test on the candidate's Form 827. If his score for the efficiency test is below the required standard at present 60 per cent, or if he fails at one or more frequencies on the pure tone test he is not accepted for aircrew training.

The candidate is then seen by the ENT Specialist who examines his ears and decides whether there is any clinical reason for rejecting him in spite of his having passed the hearing test. The Specialist makes use of any tests of hearing such as tuning forks or whispered words which may help him in the detection of aural disease.

The efficiency test and the pure tone test have now been in use for six months as the official test of hearing for the flying branch of the R A F and they have proved quite satisfactory. The rejection rate of the new test is slightly higher than that of the 20 feet forced whisper test, but it is believed that a better selection of candidates will be provided with consequent reduction in the number who have subsequently to be regraded on account of hearing defects. Owing to the smallness of the number of candidates who are now being accepted for flying training it will, of course, be several years before a full assessment can be made of the effect of these new hearing standards.

# SOME EXPERIMENTS WHICH INDICATE THAT THE FROG'S LAGENA HAS AN EQUILIBRIAL FUNCTION

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THE following experiments resulted from an inspiration received after reading the report of the electrical studies on the frog's labyrinth by D. A. Ross (1936). He recorded and studied action potentials set up in the frog's VIIIth nerve in response to vestibular and vibrational stimuli. He concluded: "Gravity receptors fall into two classes: type (i) responding best when the head is tilted out of the level position, and type (ii) signalling only the return of the previously tilted head to level. Type (ii) receptors have not been encountered often, but so far they have always been found on the posterior ramus. It is tentatively suggested that of the three organs of unknown function found on the course of distribution of the posterior ramus (*i.e.* the lagena, the pars basilaris, and the pars neglecta) one is a vibration receptor, one a gravity organ type (i), and the remaining one a gravity organ type (ii). No experimental evidence is yet available on the subject of which is which".

The labyrinthine (VIIIth) nerve divides into an anterior and posterior ramus. In all vertebrates the anterior ramus supplies the anterior vertical and horizontal semicircular canals, the utricle and most of the saccule. The posterior branch supplies the posterior vertical ampulla, the macula lagena, the pars basilaris or the cochlea and when present the pars amphibiorum (also called pars or papilla neglecta).

Early writers such as Hasse (1873), Kuhn (1880-1882), Retzius (1881-1884), Villy (1890) and Ayers (1892) were all concerned with the close association embryologically and anatomically of all the endorgans on the posterior branch of the VIIIth nerve (with the exception of the posterior vertical ampulla). They assumed a similar physiology for all three endorgans and as a result of their writings the lagena, the pars basilaris and the pars amphibiorum were regarded as forerunners of the cochlea and were considered to be part of the hearing mechanism.

Harrison (1903) stated that "the lagena is an endorgan which first appears in the internal ear in fishes and persists in amphibians, reptiles, birds and mammals though in the latter group it is without a sensory area".

\* Working with a special grant from the trustees of the Geoffrey E. Duveen fund.

## The Frog's Lagena has an Equilibrial Function

Alexander (1901) and Harrison (1903) engaged in a controversy as to the development of the lagena and its relationship to the pars amphibiorum and the other cochlear sense organs in the transition stage from amphibia to reptiles. Alexander cast some doubt as to whether the lagena is the same structure throughout the series from fishes to mammals. Harrison believed that the lagena and pars basilaris by partial fusion give rise to the single cochlear sac of the reptiles.

Breuer (1891) was the first to suggest that the lagena might be connected with the equilibrial mechanism of the ear. Based upon his observations of the topography of the labyrinth he argued that in the pike the lagena is in the best position to be stimulated by any up or down movement in the vertical direction, that is, movements in the frontal plane. The utricle is best suited to respond to movements in the horizontal plane and the saccule to movements in the sagittal plane. He concluded that the semicircular canals appreciate turning movements or angular acceleration and that the otoliths detect change of position and progressive movements. He further pointed out that the lagena is generally lacking in mammals who for the most part live on the ground and are not so much in need of a mechanism to detect vertical movements. They, therefore, have no lagena.

Breuer attempted direct experiments upon the lagena in pigeons. He was able to remove the lagena and part of the cochlea without disturbing the remainder of the labyrinth. A bird subjected to this operation did not show any specific abnormality in flying around the room. He attempted galvanic and direct mechanical stimulation of the lagena of the pigeon. He was not satisfied with these experiments upon the lagena. He was unable to advance any direct experimental proof for his idea that the lagena is concerned with detecting vertical movements in the frontal plane. It should be pointed out that arguments based upon the topography of an endorgan are sometimes misleading. This proved to be the case with the conclusions which Magnus drew about the equilibrial function of the saccule based upon the topography of the endorgan. When it became possible to carry out direct ablation experiments upon the saccule it was found not to have any equilibrial function. It is noteworthy, however, that Breuer was the first to suggest an equilibrial rather than a cochlear or hearing function for the lagena.

Matte (1894) described an operation in which he removed the cochlea on both sides in a pigeon. He did not mention what happened to the lagena but presumably it was damaged during the operation. He reported that when the pigeon had recovered from the operation its movements could not be distinguished from those of a normal bird.

Lee (1894) attempted direct stimulation of the lagena in the dogfish and he reported that the lagena is less responsive to stimulation than is the saccule or the utricle. He did not exclude the possibility of

# I. P. J. MacNaughtan and W. J. McNally

simultaneous irritation or damage of the other labyrinthine endorgans during his experiments.

Manning (1924) experimented with the common goldfish (*Carassius auratus*). In this fish the otoliths of the utricle, saccule and lagena are definite stones. He studied the conditioned reflex reactions of this fish to a range of sounds from 43 to 2,752 cycles. He was able to detect very definite and characteristic fin and other movements which indicated that the normal fish could hear this range of tones. When he removed the utricle and semi-circular canals the fish no longer reacted to the middle range of these tones. He devised an operation for breaking up the otoliths of the lagena and the saccule but the otolith of one could not be destroyed without some injury to the otolith of the other. After destroying the otoliths the fish no longer responded to notes above 1,300 cycles. There was no loss of equilibrium after destruction of the otoliths of the lagena and saccule. Manning concluded that for notes above 688 cycles the lagena and saccule are the receptors and of these two parts he believed the lagena to be much the more important. As further proof of his idea, he stated that in certain deep sea fish such as the cod the lagena is rudimentary or absent whereas the saccule is enormous. He suggested that sounds, particularly high pitched sounds, probably do not play much part in the lives of these fish in the depths.

Thornval (1926) operated upon the pigeon's labyrinth and he used caloric stimulation as a test. He concluded that removal of the cochlea and lagena from one or both ears did not cause any change in the vestibular reactions.

Benjamins and Huizinga (1928) removed the lagena on one and on both sides in the pigeon and they were unable to detect any abnormality in the vestibular reactions. The birds flew and landed normally; the turning reactions were normal; there was no change in the tone of the neck or wing muscles; compensatory eye reactions were normal. They concluded that the lagena is not concerned with any of the known vestibular reflexes.

de Burlet (1929) mentioned the lagena in connection with a discussion of hearing of the catfish (*Siluridae*) as though he considered it part of the hearing mechanism but he did not discuss the function of the lagena in particular.

Werner (1929) reported the results of operation upon a bony fish, the gudgeon (*Gobius niger*). The lagena was destroyed and rendered functionless at the same time that he removed the saccule but in spite of injury to both these otoliths there was no disturbance of the fish's vestibular reactions. After one experiment the lagena was the only part of the labyrinth remaining intact and yet the fish behaved as though a complete labyrinthectomy had been done. After he removed the lagena and saccule from only one side he was unable to detect any asymmetry in the fish's movements.

# The Frog's Lagena has an Equilibrical Function

Ross (see Tait 1932, p. 701) studied the electrical reactions from the saccular and lagenar nerves in the sucker (*Catostomus*) and he found that the oscillations which occurred when the head preparation was subjected to sound vibrations completely disappeared after he destroyed the lagena.

Von Frisch and Stetter (1932) removed the sacculle and lagena from a group of fifty-five common minnows (*Elnitze*) which had been previously blinded and some of the fish lived for more than a year after operation. None of the fish showed any signs of disturbance of equilibrium. Von Frisch (1936) reviewed the subject of hearing in fish and he stated that the lagena has no vestibular function but that it is concerned with hearing.

Löwenstein (1932) found that in the common minnow (*Elnitze*) none of the known equilibrium reactions are in any way affected by a bilateral extirpation of the pars inferior of the labyrinth which includes the sacculle and the lagena.

Beatty (1932) in the course of a discussion of hearing in reptiles stated that the lagena is reserved for hearing and may be considered as an uncoiled cochlea. He further stated that in insects there is nothing similar to the cochlea of mammals or the lagena of reptiles.

Forkas (1936) considered the lagena as part of the hearing organ in the guppy fish (*Lebistes reticulatus* Peters). He also stated, however, that the external semicircular canal is concerned with sound perception in the fish.

Tait and McNally found during their early investigations of the equilibrical reactions of the frog's labyrinth (McNally 1931) that severing the nerve to the lagena on one or both sides did not cause any change in the frog's vestibular reactions except that the operated frogs did have a slight wobble on coming to rest which was not present in normal blinded frogs. It was erroneously concluded that the wobble or oscillation was due to post-operative weakness. Since elimination of one or both lagenae did not cause any gross change in the known vestibular reactions, it was concluded that the lagena is not concerned with the equilibrical reactions of the labyrinth.

## Technique of Operation

To reach the lagena the posterior approach to the frog's labyrinth described by McNally and Tait (1933) was used. The nerve to the lagena is most easily severed by exposing the posterior ramus of the VIIIth nerve just as it leaves the brain cavity. The lagena nerve can be completely severed by inserting a small hook around the nerve. With practice a quick jerk severs the lagena nerve without damage to any other labyrinthine endorgan. All operations were carried out under ether anaesthesia. The frogs (*Rana sylvatica* and *Rana palustris*) were first blinded by bilateral section of the optic nerves. After recovery each frog was examined to be sure that it reacted normally to the usual



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# The Frog's Lagena has an Equilibrical Function

rotation was high enough to stimulate the remaining posterior vertical semicircular canals

To any forward tilt the biconjoint frog was unresponsive. A quick backward tilt on the table or a chin lift test elicited a response—the spectacular “irrelate reaction” described by McNally (1931, p. 13), by McNally and Tait (1933, p. 175) and by Tait and McNally (1934, p. 258). They noted that this reaction followed a backward tip in the “biconjoint” frog or a forward tip in the “bisolotricular” frog. They concluded that the irrelate reaction is the result of a spinal neural relationship between the utricles and the ampullae of the posterior semicircular canals. According to the degree of angular acceleration employed any grade of the so called irrelate reaction could be evoked in the biconjoint frog from a forward body thrust with ventriflexion to the final stage in which the frog with scrambling arms and wildly beating hind limbs kept its body oscillating in tempo with the alternate movement of its limbs.

## Two Intact Posterior Vertical Semicircular Canals, Partes Basilares and Partes Amphibiorum

If the nerves to both lagenae were severed in the biconjoint frog, the resulting “biconjoint de lagenate” frog did not show any marked difference in its reactions from the biconjoint frog.

## Two Remaining Lagenae, Partes Basilares and Partes Amphibiorum

If the nerves to the ampullae of the posterior vertical semicircular canals were severed in the biconjoint frog the resulting “biconjoint decanaliculate” frog had the lagena, the pars basilaris and the pars amphibiorum intact on both sides. The frog was able to right itself from the supine position readily. The posture of fixed axial ventriflexion in the biconjoint frog was released and the head was held low but clear of the ground. At times the arms extended laterally and the knees pointed outwards. At other times all limbs would be tucked in normally. A surprising finding and one which was repeatedly checked was that the irrelate reaction was present in response to the chin drop test and the tetanic reaction in response to the chin lift test. Tait and McNally had concluded that the irrelate reaction could be elicited from stimulation of the utricles and from stimulation of the posterior semicircular canals. The above experiments showed that stimulation of the lagena could also give rise to the irrelate reaction.

The “tetanic reaction” was described by McNally (1931, p. 11) and by McNally and Tait (1933, p. 175). The reaction was first noted in a frog in which the nerves to both posterior vertical ampullae had been severed. When such a frog is tipped backwards or subjected to the chin lift test under ordinary circumstances the head is raised and the arms are

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extended forward and the body slews back slightly between the thighs. Sometimes, however, just at the top of the movement the frog develops what might be termed tetany. The arms become more rigidly extended, the body is curved backward, the legs are extended outwards and laterally and the whole body trembles with spasm as if by avalanche action the frog is made actively to rear upwards when it is suddenly chucked under the chin. Sometimes the animal will actually go off the tilt table as though doing a backwardly directed swan dive. At other times the spasm passes after a few seconds and the animal recovers and stays on the table. This reaction was first noticed usually after sectioning the nerve to both posterior vertical canals but occasionally after sectioning the nerve to one canal. The occurrence of the tetanic reaction in the "biconjoint decanaliculate" frog shows that stimulation of the lagena could also give rise to the tetanic reaction.

## One Intact Lagena, Pars Basilaris and Pars Amphibiorum

If in the biconjoint de-canaliculate frog one labyrinth was completely destroyed, the frog after recovery still showed a prompt righting reflex. It usually turned from the supine to the prone position with the operated side under. The irrelate and tetanic reactions were not elicited in these frogs which had only one lagena intact.

## The Pars Basilaris and the Pars Amphibiorum Intact in one or both Labyrinths

It did not prove possible to carry out uncomplicated severance of the nerves to the pars basilaris or to the pars amphibiorum. In order to get some idea of their relation to the equilibration reactions of the frog the nerves to the two lagenae were severed in the biconjoint de-canaliculate frog leaving only the nerves to the partes basilares and partes amphibiorum intact. One could not distinguish these frogs from the de-labyrinthized frog. In other experiments the pars basilaris and the pars amphibiorum were kept intact in only one labyrinth. Again these frogs could not be distinguished from the de-labyrinthized frog. They showed the righting reaction only occasionally and they did not show any tetanic or irrelate reactions. There was no reaction to quick or slow tilt back into level position (Ross' gravity receptor type (ii)).

## Interaction between the Lagena and the Utricle

McNally and Tait (1933) and Tait and McNally (1934) reported that a pendular oscillation occurred in frogs which had had an ablation of any two diagonal vertical semicircular canals or an ablation of the four vertical semicircular canals. The pendular oscillation was also reported in frogs with only the two utricles intact. The pendulation was particularly noticeable at the beginning and end of any movement. The

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amount of pendulation varied somewhat from frog to frog but the significance of any variation in pendulation was not recognized until the present series of experiments had shown that the lagena has some equilibrical function. It occurred to one of us (I. P. J. McN.) that there is a significant difference between the pendulation of a frog with only two utricles remaining intact and the pendulation of a frog from which all six semicircular canals have been removed. It was decided to compare a series of frogs subjected to each method of operation.

## "Bisolutricular" Frog

The posterior vertical semicircular canal can be ablated by sectioning the whole posterior ramus of the VIIIth nerve. The nerve to the saccule can be severed at the same time as are the nerves to the ampullae of the horizontal and vertical semicircular canals. Such a frog has only its two utricular maculae remaining intact—it is what the name signifies, a "bisolutricular" frog.

On attempting any movement this frog invariably showed a marked pendular oscillation of the head and body. This pendulation was first described by McNally and Tait (1933) in the case of the frog in which all four vertical semicircular canals had been removed and by Tait and McNally (1934) in the case of the frog with only the two utricles remaining intact. It was concluded that the utricles are responsible for this pendulation.

The reaction in the "bisolutricular" frog under discussion was so severe as frequently to upset the frog during its attempt to compensate for a slow tilt on the tilt table. The number of pendulations on coming to rest after being disturbed averaged six to eight times. The righting reaction was prompt. To a quick tilt, the bisolutricular frog showed a prompt anti-compensatory slew of the body in the direction of a tilt—a reaction which Tait and McNally (1934) termed the second mode of utricular response.

## "Decanaliculate" Frog

When the terminal branch of the posterior ramus of the VIIIth nerve was severed just before it reached the ampulla of the posterior vertical semicircular canal, this canal was functionally ablated. When the nerve to the saccule was left intact when severing the nerves to the ampullae of the horizontal and vertical semicircular canals such a frog had intact in addition to the utricles the saccules, the lagenae, the partes basilares and the partes amphibiorum. When the operation was bilateral the frog was "decanaliculate."

On attempting spontaneous movements the decanaliculate frog showed pendulation but it was less marked than the pendulation of the bisolutricular frog. The number of pendulations on coming to rest after

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being disturbed averaged two to four times. The head swayed in the arc of a circle and sometimes if the head was brought up suddenly a spontaneous "irrelate" reaction was precipitated. Its righting reactions were more obvious because the pendulations were less. In response to a quick tilt this frog also gave the anti-compensatory reaction, the result of the second mode of utricular stimulation mentioned in discussing the reactions of the "bisoliutricular" frog.

In order to prove that it was the lagena which lessened the pendular oscillation in the "decanalicate" frog the nerves to the lagenae were severed in this frog. After recovery from operation such a frog showed a definite increase in pendulation. It could not be distinguished from any "bisoliutricular" frog.

The following table is reproduced to emphasize the difference which the presence or absence of the lagena made in a frog from which all six semicircular canals had been removed.

	" Bisoliutricular " frog	" Decanalicate" frog
Pendulations at the beginning and end of movements	Averaging 6 to 8 times	Averaging 2 to 4 times
Righting reaction	Present	Present
Irrelate reaction	Present	Present
Reaction to slow tilt	Accurate (Pendulation troublesome)	Accurate (Occasional pendulation)

## Ablation of Four Vertical Semicircular Canals

Severing the nerves to the four vertical semicircular canals leaves the frog with the following endorgans still intact on each side, the horizontal semicircular canal, the utricle, the saccule, the lagena, the pars basilaris and the pars amphibiorum. The detailed reactions of this frog have been described by McNally and Tait (1933). The frog pendulates when disturbed, the number of pendulations averaging about two to four on coming to rest. Severing the nerves to both lagenae in such a frog definitely increases the number of pendulations to an average of six to eight after each movement.

## Ablation of any diagonal pair of Vertical Canals

The reactions of this frog have also been described in detail by McNally and Tait (1933). During or after spontaneous movements such a frog pendulates in the plane of the absent vertical canals. Removing the lagenae in such a frog definitely increases the number of pendulations.

It should be noted that some frogs tend to pendulate more than others with apparently the same labyrinthine lesions. Naturally the better the

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general condition of the frog the better are all the reactions. Removing the lagenae in the great majority of cases does increase the tendency to pendulation but not in every case.

## Résumé

1. The lagena is an endorgan which is present in the labyrinths of fishes, amphibians, reptiles and birds.
2. The majority of writers were of the opinion that the lagena is part of the hearing mechanism.
3. Breuer (1891) was the first to suggest that the lagena is connected with the equilibril part of the labyrinth.
4. Ross (1936) suggested the presence in the frog of at least one and probably two gravity receptors on the posterior ramus of the frog's VIIIth nerve in addition to the posterior vertical semicircular canal. Our experiments show that the lagena is one of these gravity receptors.
5. Removal of one lagena causes a residual pose consisting of a slight upward tilt on the homolateral side. Removal of both lagenae causes very little disturbance in the frog's vestibular reactions. There is a slight oscillation of the head on coming to rest after spontaneous movement.
6. A frog with both lagenae intact in the absence of all the known equilibril endorgans, still retains a prompt righting reflex. It gives the irrelate and tetanic reactions in response to certain head movements showing that the lagena is an equilibril endorgan.
7. The lagenae together with the vertical semicircular canals control and check utricular pendulation. Normally during movement the vertical semicircular canals and also the lagenae have a controlling or regulating influence upon the utricles.
8. These experiments do not throw any light upon the identity of Ross's probable third gravity receptor on the posterior ramus of the frog's VIIIth nerve. As far as these experiments do go they indicate that the pars basilaris and the pars amphibiorum have no equilibril function.

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We are much indebted to Dr. E. A. Stuart for his help in searching the literature.

# CLINICAL RECORDS

## VESTIBULAR CYSTS

By A S HANDOUSA BEY (Cairo)

THERE is a special group of cyst, which we Rhinologists occasionally meet with in the region of the anterior nasal aperture, cysts proved not to be of dental origin and have been given different terms in different countries. In the English literature they were grouped under the term Cysts of the Floor of the Nose, while other observers have termed this same group of cysts—Mucous Cysts, Cysts of the Alae Nasi, Cysts of the Entrance of the Nose Vestibular Cysts, etc.

Fig 1 is a typical example of such cysts. I have had 10 cases of various sizes, study of which reveals certain points worth mentioning.

The age incidence in my group of cases is 14-50 years. 6 were males. They were all single and mainly left sided. bilateral cases were reported in the literature and have been even considered by some as commoner than unilateral ones. According to Bernfeld (*J Laryng and Otol* April 1945) multiloculation has never been seen or recorded. Fig 2 is an X ray after lipiodol filling of one of my group of cases, demonstrative of biloculation and it is quite possible that by such methods of investigation more examples of multiloculation may be found.

In the majority of cases that I have investigated the *aspirated fluid clotted* soon after being collected in the test tube, an observation which I have not come across in the literature.

In *diagnosis*, exclusion of dental origin may be not easy before exploration. Every now and then one comes across a case which appears typical of a vestibular cyst as regards site, radiological appearance without and with lipiodol and in its fluid content but on exploration, the bare tip of the root of a tooth is found just projecting in the cyst cavity—a finding very suggestive of dental origin. It seems to me advisable before a final diagnosis to make sure of this point.

A final point which I believe will be of great value in medical practice is an agreement about a *general term for this group of cysts*. They are fully recognized as a special group of their own for more than 50 years and in spite of this there has been no unanimity of the term allotted to them.

A terminology depending on the nature of these cysts is not practical as it is very difficult to be certain of this even after biopsy in the majority of cases.

Authorities differ as to their genetic origin, one school considers them as '*Genuine retention cysts*' derived from the glands lying in the vestibule, while another school tend to consider them of '*Developmental Origin*' related to the lacrimal duct or in connection with the facial clefts. Only in few cases has the origin been ascertained. I have had one case, the 5th,



## A. S. Handousa Bey

among my series, that followed a sublabial incision and was histologically proved to be a salivary cyst.

*It seems to me that the most applicable term, would be a term related to their site as it covers the whole group.*

All the small cysts that I have seen were found in the anterior part of the nose, occupying the lateral vestibular angle more related to the lateral wall than the floor. Fig. 3 is a demonstrative example.

Large cysts are seen extending more laterally than medially or backwards, lifting up the corresponding ala and outer wall of the nose, suggesting the same site of origin. I have had a case, in which the cyst has extended to the opposite side X-ray 4, Photo 5 ; even in this case as there were more lateral extension to the canine fossa, I could not convince myself that the cyst has started in the Nasal Floor.

Further I have never seen or come across a case reported to originate in the floor of the nose behind the vestibule, and the large amount of literature on the subject examined by Bernfeld (*J. Laryng. and Otol.*, April, 1945) confirms the site of origin described above.

These considerations favour the general term of *Vestibular Cysts* or Cysts of the Entrance of the Nose ; the former is much easier to use, and is suggested to be chosen to cover this group of cysts.



FIG 1



FIG. 2.



FIG 3



FIG. 4.



FIG 5



## A CASE OF SUBDURAL ABSCESS SECONDARY TO ACUTE FRONTAL SINUSITIS

By P C RUSHTON (Cambridge)

THE patient, a girl aged 12, was admitted to Addenbrooke's Hospital on 30.4.46 with a ten days history of pyrexia, increasing lethargy and frontal headache. No physical signs had been found to account for this, except a slight swelling over the bridge of the nose on the morning of admission.

On examination she had a temperature of 101° F, pulse 60, and respiration 20. She was ill-looking, flushed and rather lethargic. There was some oedema over the bridge of the nose and over the right eyebrow. There was slight tenderness to pressure over the floor of the right frontal sinus, but none over the left. The right middle turbinate was bright red and swollen, this being the only abnormality in an otherwise normal looking nose. K J's, A J's and abdominal reflexes all normal, Babinski's sign was negative. Nothing abnormal was detected in the cranial nerves.

*X-Ray*—Opacity of the right antrum and both frontal sinuses. Under local anaesthesia the right antrum was punctured, and thick greenish, foul-smelling pus washed out. A short cannula was left in the antrum, and tampons soaked in 1 per cent Ephedrine in Normal Saline were placed under each middle turbinate. 20,000 units of Penicillin were given intramuscularly, and continued every three hours. The right antrum was aspirated every three hours and Penicillin, 2,000 units per c.c., was injected through the indwelling cannula. The next day there was no apparent change in her condition, and this conservative treatment was continued.

The next day, 2.5.46 she appeared more lethargic and the swelling had increased spreading to the left side and to both upper eyelids. Her eyes were examined and the following report submitted: "Well marked bilateral papilloedema suggests presence of increased intracranial pressure. Some swelling upper lids. Paralysis of right External Rectus muscle. ?Slow cerebation."

*Operation*—2.5.46 A lumbar puncture was first done whilst under the anaesthetic. 5 c.c. of clear fluid were withdrawn under normal pressure (This fluid was examined in the laboratory, and no abnormalities were found in it).

The left antrum was then punctured and found to be uninfected. A right intra nasal antrostomy was performed.

A large incision was then made over the right frontal sinus, and the sinus opened. It was found to be full of thick yellow pus, the lining mucosa being only slightly oedematous. The sinus was seen to fill up with pus after it had been emptied. The posterior wall appeared intact, but after removing almost the entire anterior wall a pin point hole was seen in the lateral corner of the posterior wall through which a thin stream of pus was pouring. On opening



the posterior wall about 20 c.c. of thick blood-stained pus poured out under considerable pressure. This opening was enlarged and the dura was found to be intact, and covered with fine red granulations. The abscess cavity spread backwards towards the temporal bone, a probe could be passed easily backwards and laterally for 4 inches. The mucosa of the floor of the sinus and the fronto-nasal duct were not interfered with. The left frontal sinus was then opened by breaking down the intersinus septum and more thick yellow pus evacuated. A narrow rubber catheter was placed in the abscess cavity, and another in the left frontal sinus. The wound was then closed after a small piece of corrugated rubber drain had been placed in the right frontal sinus.

*After-treatment.*—(i) Intramuscular penicillin was continued.

(ii) Sulphadiazine gms. 1 was given, followed by gms.  $\frac{1}{2}$  3 hourly.

(iii) After aspiration of any pus or serum from the two catheters, the equivalent amount of Penicillin, 2,000 units per c.c. was injected every three hours.

*Organisms.*—The pus from the frontal sinus produced a culture of Penicillin-sensitive *Staphylococcus albus*. The pus from the subdural abscess showed clumps of Gram-positive cocci, but the culture was sterile.

*Progress.*—There was an immediate and lasting improvement of her general condition. The next morning she was bright and cheerful, and one only realized then the full degree of her previous lethargy. Her temperature fell and remained normal. The paralysis of her right external rectus disappeared on the first day.

On the third day she developed a painless, fluctuant swelling, 3 inches in diameter, in the mid-line on the upper part of her forehead. This was first aspirated, but the pus was too thick, so an incision was made into this secondary abscess and 10 c.c. of thick pus was evacuated. Bare bone was felt at the base of the abscess. A small rubber drain was inserted, and this gave no further trouble. No further complications ensued.

On the seventh day the stitches and the rubber drain were removed. On the eighth day the sulphadiazine was discontinued, 26 gms. having been given.

On the tenth day the catheters were removed, but intramuscular Penicillin was continued until the sixteenth day, when it was stopped after she had received 2,380,000 units.

She was discharged as quite fit on 30.5.46.

Although almost all the anterior wall of her right frontal sinus was removed, there is only a very small depression, but if in the course of time this becomes more marked, it may be necessary to repair the defect by bone chips after obliteration of the nasofrontal duct.

## LETTER TO EDITOR

TO THE EDITOR, *The Journal of Laryngology and Otology*.

DEAR SIR,

I shall feel obliged if you will publish a correction which I wish to make in my article on the "Function of the Labyrinth".

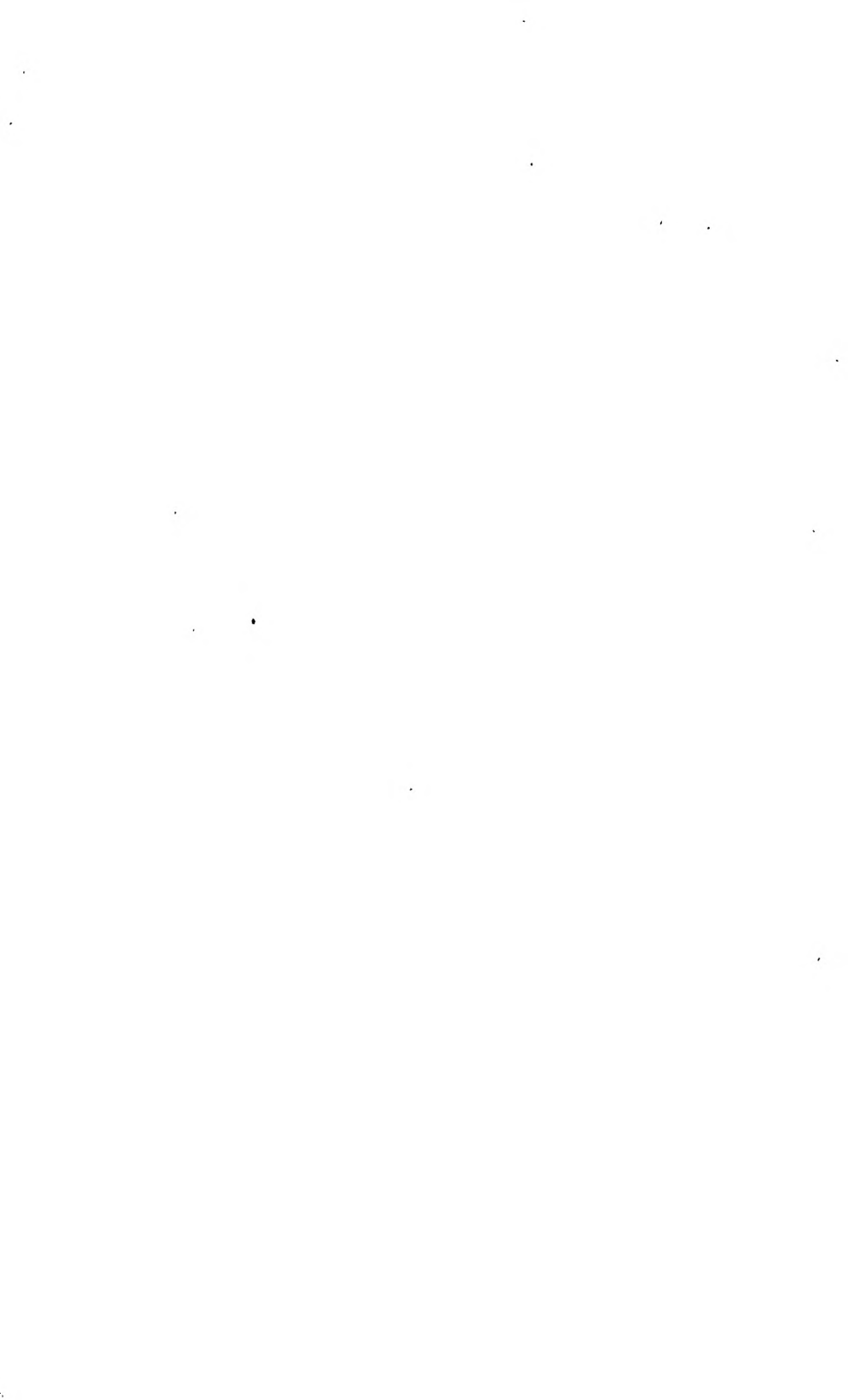
On page 432 of the *Journal*, vol. LX, No. 11 in the paragraph commencing "The fluid of the vestibule" the words "on the arrest" should not have been inserted. It should read as follows :

"On the cessation of a movement of the head, the entire energy is in the momentum which, if the fluid were free to move, would carry it with corresponding force against the wall of the vestibule in the *direction towards which* it had been moving.\* The fenestra is at its anterior end, on its outer side, and on any movement or rotation of the head to the opposite side, the fluid would be carried against the stapes which would be forced outwards.

Yours etc.,

H. MACNAUGHTON-JONES.

\* A movement of the head from rest in the reverse direction would produce exactly the same relative movements. The movement is, substantially, one of the vestibule and fenestra over a column of relatively stationary fluid, and the stimulus is, therefore, simultaneous with the movement of the head.



# The Journal of Laryngology and Otology

(Founded in 1887 by MORELL MACKENZIE and NORRIS WOLFENDEN)

*April 1946*

## A SUGGESTED METHOD FOR MEASURING THE ATTENUATION OF SOUND BY FLYING HELMETS\*

By Air Commodore E. D. D. DICKSON, Sq. Leader D. B. FRY,  
Flight Lt. G. E. SWINDELL, Flying Officer R. E. C. BROWN

### 1. Introduction

It is important from two points of view that air-crew personnel should be afforded adequate protection from the ambient noise present in Service aircraft. First, the efficiency of any communication system using auditory signals will be directly related to the masking level of the noise at the ear of the listener, and second, the temporary or permanent damage to hearing which may result from exposure to the noise will depend on the protection afforded. A protective device such as a flying helmet should, then, be assessed according to its efficiency in reducing the level of the components of the noise at the ear. The common methods of measuring the efficiency of a flying helmet are subjective ones which differ from each other only in details of experimental technique. The present paper suggests reasons for replacing the subjective methods by a more objective one and describes such a method which has been used in this laboratory.

### 2. Subjective Attenuation Measurements

Subjective measurements of the sound attenuation of helmets are usually carried out by noting the rise in the threshold for a series of pure tones when a helmet is interposed between the ear and the source of sound. In the technique adopted by the Psycho-Acoustic Laboratory of Harvard

\* This research work has been carried out in the Acoustics Laboratory, Department of Otorhinolaryngology, Royal Air Force, Central Medical Establishment.

University\*, pure tones are generated by a beat frequency oscillator and reproduced by a loudspeaker and the subject controls the voltage input to the loudspeaker in order to arrive at his threshold for the series of pure tones. Differences between the threshold when wearing a helmet and the unprotected threshold are taken as being equal to the amount by which the helmet attenuates the various frequencies.

Some such method is commonly used for making subjective measurements of attenuation. Two modifications of the Harvard method have been adopted in this laboratory. At Harvard, the subject has one ear tightly plugged and sits with the unplugged ear turned towards the loudspeaker; here, the subject uses both ears and sits facing the loudspeaker. In this laboratory, too, the input voltage to the loudspeaker is controlled not by the subject but by an operator who, to obtain each reading, gradually increases the input until the subject signals that his threshold has been reached.

Determinations made by these subjective methods show a great deal of variation from individual to individual. In the experiments carried out here the individual determinations scattered so widely that in general the differences registered between helmets could not be relied upon. Not only did the results vary from one subject to the next but it was impossible to ensure that one subject should always give the same result for the same helmet. This variability was no doubt due in part to variation in the acoustic seal provided by the helmet from one experimental run to the next and it may be argued that it is of interest to know whether the fit of a given helmet is so critical as to cause wide differences in the subjective judgments of its attenuation. A helmet in which this is the case, even though in its optimum condition it may give very good attenuation, is clearly not a good helmet for general use. On the other hand, such variations in the judgment for one helmet preclude the possibility of assessing small differences between helmets and thus restrict the usefulness of such measurements. It is desirable to be able to detect not only the difference between one helmet and another which is perhaps slightly superior but also the effect of a small modification to a helmet, such as, for example, a change in the material used for the telephone holders.

The need for a more sensitive method of measurement has led to an attempt to devise an "objective" method in which the ear judgments shall be replaced by instrumental readings.

### 3. Objective Attenuation Measurements

In theory it should not be difficult to replace the ear by a microphone and to make the required measurements by means of a sensitive voltmeter.

\* See "The Acoustic Design of Earphone Sockets for Helmets and Headsets". (Psycho-Acoustic Laboratory, Harvard University)

# Measuring Attenuation of sound by Flying Helmets

In principle the method is similar to the subjective method. The microphone is placed near a sound source supplying pure tones of different frequencies and the voltmeter is used to measure the voltage developed across the microphone both when it is open to the sound source and when it is "protected" by a helmet. The difference between readings for the two conditions gives the attenuation of the pure tones by the helmet. The considerable practical difficulties that are encountered in applying such a method are described in a subsequent section. A report on similar work has been made by Squadron Leader H. A. Robinson R.C.A.F. to the Associate Committee on Aviation Medical Research N.R.C., Canada. This paper describes the measurement of the attenuation of various materials which can be used in making helmets and therefore supplies information which is of service when designing a helmet or its component parts. The efficiency of a helmet in attenuating noise is limited, however, by the efficiency of its weakest part and it is therefore necessary to be able to measure the attenuation afforded by the helmet as a whole. This report describes the experimental work which was carried out with a view to devising a technique for making such measurements.

## 4 Apparatus

The apparatus used in carrying out the objective attenuation measurements will now be described. It can be divided into two main sections, (a) the signal generating system, by means of which the signals are produced and presented to the artificial ear, and (b) the measuring system, which includes the artificial ear itself and the meter on which the output from the microphone is measured.

### 1 Signal generating system

This system is shown schematically in Fig. 1. It consists of a Birmingham Sound Reproducers beat frequency oscillator which is connected directly to a large Pamphonic moving coil loudspeaker mounted in a testing booth. The voltage applied to the loud speaker can be measured on the meter included in the output circuit of the oscillator. The inner walls of the booth are lined with varnished plywood and in order to reduce reflection a heavy curtain is provided which can be drawn in front of the three blank walls.

When measuring the amount by which a helmet attenuates a complex noise the oscillator is replaced by the noise generator described in a previous report\*. This generator makes use of an engine noise recorded as a sound track on a glass disc. A beam of light is focussed on the disc which is mounted on the shaft of an electric motor. The modulated beam then acts upon a photo electric cell and the resulting

\* See A New Method of Testing the Hearing Efficiency of Aviation Candidates F.P.R.C. 532 March 1943

SCHEMATIC DIAGRAM OF APPARATUS USED IN  
OBJECTIVE ATTENUATION MEASUREMENTS

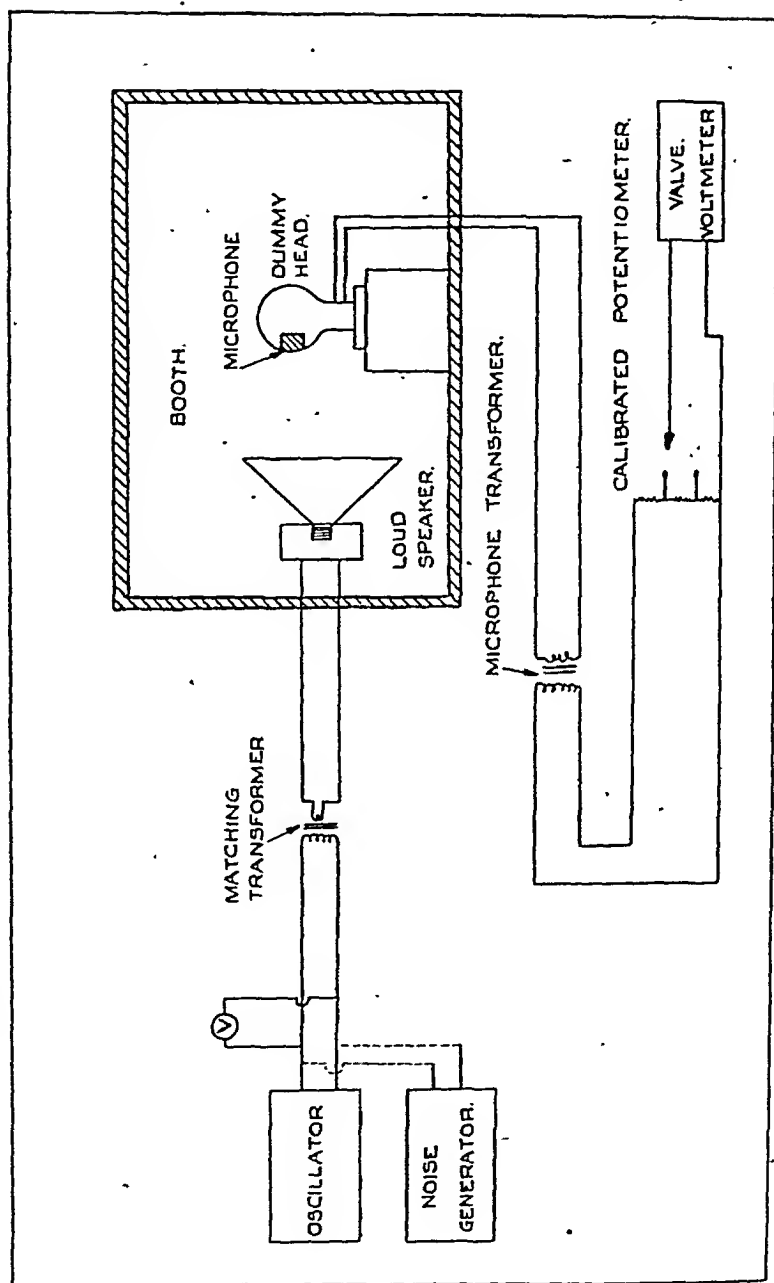


FIG. 1.

# Measuring Attenuation of sound by Flying Helmets

voltage variations are led to the input of a 50 watt amplifier. A transformer is included in the output circuit of the amplifier in order to match its impedance to that of the loudspeaker.

## 2 *Measuring system*

The measuring system consists of a Standard Electric moving coil microphone, No 4017a, and a high gain valve voltmeter on which the signals received by the microphone are measured. This microphone which has a reasonably flat frequency characteristic throughout the range 50 to 10000 c.p.s., is mounted in a dummy head and acts as an artificial ear. The dummy head is of the type used in the manufacture of flying helmets and is composed of a layer of papier mâché about  $\frac{1}{4}$  in thick and mounted on a wooden base. The interior of the head used in these experiments is packed with plastine and the microphone inserted so that it lies a little below the surface of the head. This ensures that only those signals which fall on the diaphragm of the microphone are registered. Sound waves which fall on any other part of the head are absorbed by the plastine and prevented from reaching the microphone. This packing also serves to prevent any considerable build up of signal strength owing to resonances in the interior of the head. Since there was a possibility that the diaphragm of the microphone might extend beyond the telephone holder of some helmets a thick ring of plastine was placed in front of the microphone in order to reduce the area of the diaphragm exposed to the sound.

The valve voltmeter consists of a two stage high gain amplifier with a moving coil current meter in the output circuit. The input to the amplifier, which has an impedance of 1 megohm is fed through a calibrated potentiometer covering a range of 112 db in steps of 4db. The voltage variations across the input are recorded on the output meter which is calibrated in decibels about a centre zero. The overall gain of the amplifier is 114 db and the zero reading on the meter with maximum gain corresponds to a voltage of 144 microvolts across the microphone.

## 5 *Experimental Technique*

The protection afforded by each type of helmet was estimated in two ways (a) by measuring the amount by which pure tones are attenuated, and (b) by measuring the decrease in the overall level of a complex noise on passing through the helmet. The method of carrying out these measurements is described in the following section.

### 1 *Pure tone attenuation measurements*

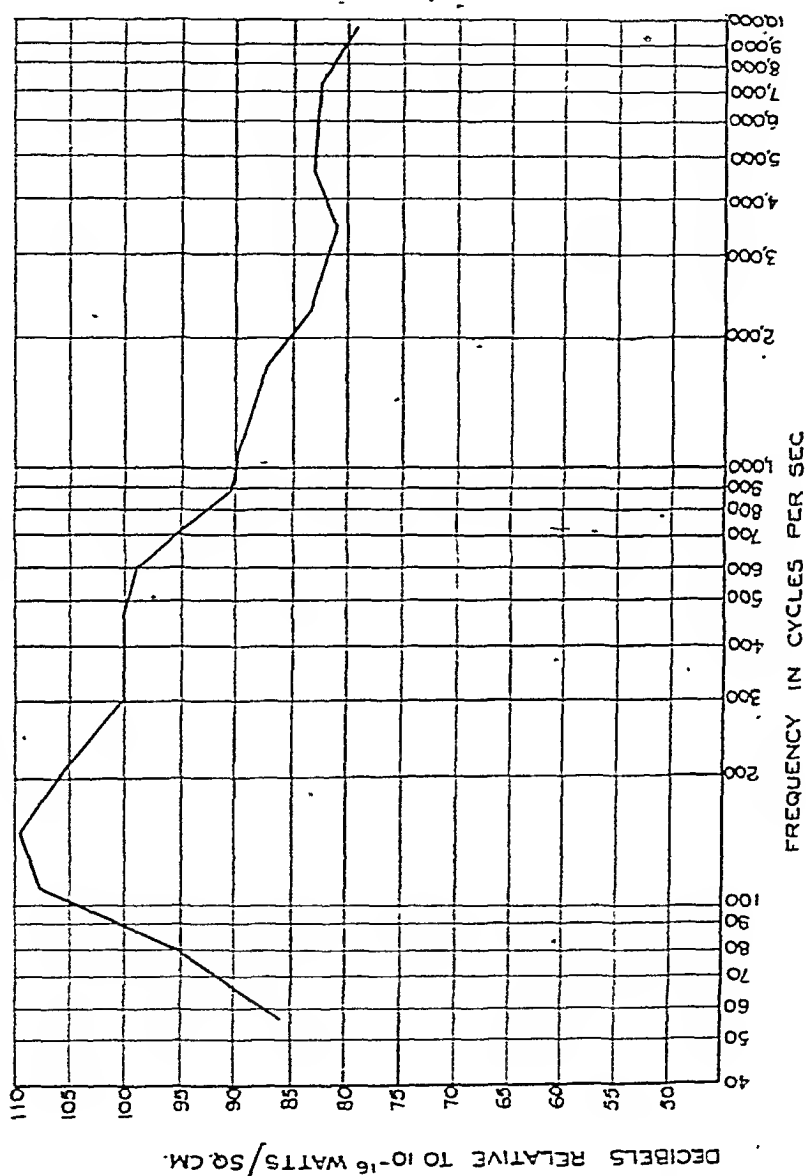
In making these measurements the head was placed so that the microphone faced the loudspeaker at a distance of about 18 in from the centre of the cone. The reading on the output meter of the oscillator, which was kept fixed at all frequencies, was so chosen that the level of



# Dickson, Fry, Swindell, Brown

the signal when the microphone was protected was sufficient to produce a reasonable deflection on the voltmeter at every frequency used in the test. When taking a reading the calibrated potentiometer on the input

FIG. 2.  
SPECTRUM OF COMPLEX NOISE.



of the voltmeter was adjusted so that the meter needle was brought as close as possible to the centre zero. As the scale on this meter is calibrated in decibels it is possible to interpolate between the 4 db. steps

# Measuring Attenuation of sound by Flying Helmets

on the potentiometer and so estimate the setting which would bring the needle exactly to zero

The difference between the settings corresponding to zero reading when the head is exposed to the sound and when it is protected by a helmet gives the attenuation of the helmet at that frequency. It proved to be impossible to make measurements at frequencies greater than about 8000 c p s. The efficiency of the loudspeaker falls considerably at these high frequencies and thus, added to the fact that most flying helmets attenuate sounds in this region by 40 db or more, made it impossible to produce signals of sufficient intensity to give a reasonable deflection on the valve voltmeter. It was decided therefore to confine the attenuation measurements to frequencies within the range 100-8000 c p s.

In sweeping through the frequency range and keeping the output from the oscillator constant it was seen that the curve representing the microphone voltage passes through a large number of sharply defined peaks. These are due partly to peaks in the frequency response of the signal generating system and partly to the effect of standing waves set up in the testing booth. The peaks in the output from the microphone were found to occur at almost exactly the same frequencies for "protected" and "unprotected" measurements, the only difference being that for the protected measurements the peaks tended to be less sharp. Unless the oscillator is tuned to correspond with the maximum of the peak a small error in the frequency setting may lead to a large change in the voltmeter reading and so give rise to spurious attenuation values. Tuning to the crest of the peak also has the advantage of increasing the output from the microphone and making it possible to cover a larger range of frequencies. It was decided therefore to take readings at certain selected peaks throughout the range and to tune to the maximum of these peaks for both protected and unprotected measurements.

The technique employed in making an attenuation measurement can be stated as follows:

The head is placed in position in front of the loudspeaker and the frequency dial of the oscillator set close to one of the required values. The frequency is then adjusted slightly so that it corresponds with the nearest peak in the output from the microphone and the output voltage of the oscillator is set at a fixed value, as mentioned above. The potentiometer in the voltmeter is then adjusted to bring the needle on the meter as close as possible to the centre zero, and the setting which would correspond accurately to the zero reading is calculated. This setting is noted for 10 frequencies throughout the range, the frequencies actually used are shown in Table 1, page 229.

The helmet under test is then placed on the head. It is important

to ensure that the telephone holder is located centrally over the microphone. For this reason the earpieces are not inserted until the helmet is adjusted so that the microphone appears to be directly opposite the telephone holder. The chin straps are done up firmly but not too tightly and the earpieces are carefully replaced in such a way that the hole through which the telephone leads normally pass is covered by the telephone holders. In the case of helmets where the telephones are inserted from the inside this procedure is not possible but instead great care is taken to ensure that the telephone shall be as nearly opposite to the microphone as can be judged from external appearance.

When the helmet is on the head the measurements are repeated, the output of the oscillator being kept at the same fixed value for all frequencies. As before, the frequency is adjusted to correspond with a peak on the microphone output. In almost all cases this has been found to be within a few cycles of the corresponding reading for the unprotected measurement.

The setting of the potentiometer which would give zero reading on the voltmeter is again calculated and the difference between the two settings for protected and unprotected conditions gives the attenuation effected by the helmet at each of the selected frequencies.

When the complete set of attenuation determinations was repeated after removing and replacing the helmet it was seen that the values showed some variation. This variation was seldom greater than 5 db. and then only at the higher frequencies. When an attenuation measurement was repeated without removing the helmet the values obtained never varied by more than 1 db. thus showing that the variations previously noted are produced by the removal and replacing of the helmet. They may be caused by a change in the pressure with which the helmet is applied to the sides of the head or in some other factor affecting the seal between the helmet and the head. When the receivers were pressed tightly against the sides of the head by means of a spring clip the measurements were found to agree more closely. This very considerable pressure, however, increased the attenuation afforded by the helmet and it would be misleading to quote these values as such a pressure could not be applied when the helmet is in normal use.

Because of this slight variation in the results it was decided to carry out three complete determinations for each helmet, which was removed and replaced in the manner described above, and to take the mean of the values of attenuation obtained at each frequency. The unprotected readings did not change by more than 1 db. and it was not necessary to repeat these. By making attenuation measurements with the head in various positions in the booth it was shown that the position of the head in relation to the loudspeaker is not critical. From this it would seem to follow that the peaks obtained in the output from the microphone are

# Measuring Attenuation of sound by Flying Helmets

in the main due to peaks in the response of the signal generating system rather than to the effects of standing waves in the booth

The intensity level of the pure tone signals used in making the measurements was determined by means of a General Radio Sound Level Meter. The level of each signal above the standard reference intensity is given in the following table

TABLE I

FREQUENCY	INTENSITY
c p s	db
100	103
250	110
345	107
620	112
960	105
1800	104
3270	96
4780	99
5915	81
7540	61

It is seen from this table that the pure tones were all of rather high intensity, and in fact were comparable in intensity with the components of aircraft noise. This constitutes a further difference between this objective method and the common subjective method, which uses low intensities. As far as the objective method is concerned, there is, however, no reason to suppose that the actual level of the pure tones would have any influence on the results. There is little doubt that an attenuation value for a signal of given frequency will hold good whatever the level of the signal.

## 2 Attenuation of a complex noise

Overall noise attenuation measurements have been carried out on the various types of helmet using the complex noise referred to in Section 4. In making these measurements the output from the noise generator was led directly to the loudspeaker and the intensity of the noise issuing from the speaker was kept constant at 110 db as measured on the G R meter. The head was then placed in position as before and the output from the microphone recorded on the valve voltmeter for both protected and unprotected conditions. Three determinations were made for each helmet, the helmet being removed and replaced each time. It was found to be unnecessary to repeat the unprotected reading on each occasion. The individual measurements for a particular helmet showed such slight variation (never more than 3 db) that this repetition of the determinations was not strictly necessary.

The mean values of overall attenuation obtained for the various helmets are shown in Table II, Section 6.

## 3. *Comparison of spectra of complex noise inside and outside helmet*

By a variation of the technique described in section 5.2 it is possible to obtain a check on the pure tone attenuation measurements. This consists in plotting the spectrum of the noise picked up by the microphone for protected and unprotected conditions. The reduction in intensity in a particular frequency band, provided the band is sufficiently narrow, should then agree roughly with that given by the pure tone measurement at a frequency corresponding to the middle point of the band. This procedure was adopted for several of the available helmets.

The head was placed in position in the noise field and the output from the microphone led through the valve voltmeter amplifier to a General Radio Sound Analyser. This analyser measures the intensity of the sound in a frequency band extending over a range equal to 5 per cent. of the frequency to which the instrument is tuned. Readings were taken at the frequencies used in the pure tone measurements. The helmet was then placed on the head and these measurements repeated. The difference between the two sets of readings then gave the attenuation for each of the frequency bands.

When the synthetic aero-engine noise was used for these measurements the results were satisfactory for frequencies up to 1000 c.p.s. but above this frequency difficulties were encountered owing to the fact that the filters in the sound analyser provide a maximum attenuation of the order of 40 db. for frequencies outside the band to which they are tuned. If, therefore, there is a difference of more than 40 db. between the intensities of two components of the noise it will be impossible to measure the weaker component as the stronger one is likely to be registered at the same time thus giving spurious results. The helmet may attenuate the high frequencies by 50 db. more than the extreme low frequencies and as the noise is in any case less intense in the high frequency region the difference in intensity between the components can easily exceed 40 db. Readings for frequencies in the middle and upper parts of the range are therefore very likely to be spurious and due entirely to the effect of the more intense low frequency sounds which break through the filtering system. In order to overcome this difficulty and to make measurements possible above 1000 c.p.s. the readings were taken for the two parts of the range separately. For bands up to 1000 c.p.s. the total synthetic aero-engine noise was used, and for frequency bands above this, the valve generated noise only was used. This noise has a fairly uniform spectrum from 1000 c.p.s. upwards. Components below this were reduced in intensity by means of a separate high pass filter. With this type of noise it proved possible to take readings throughout the range, 1000-7500 c.p.s. Attenuation measurements were then carried out at the frequencies used in the pure tone measurements, and these, taken in conjunction with the low frequency measurements using the standard

# Measuring Attenuation of sound by Flying Helmets

engine noise, gave the values of attenuation throughout the frequency range 100 7500 cps

The purpose of this experiment was to show that, for a given helmet, attenuation values obtained by the pure tone method are a reliable indication of the amount by which the components of a complex noise are attenuated. The measurements show that there is good agreement between the results obtained by the two methods (see Table III, Section 6) and it follows from this that we are justified in calculating the spectrum of the noise inside a flying helmet worn in a noise field by reducing the intensity of each component of the external noise by an amount equal to the pure tone attenuation at the corresponding frequency

## 6. Results

The method described in Section 5.1 has been used to measure the attenuation of 11 different helmets and 1 head band. The following table gives some information about all the helmets measured. Except where it is otherwise stated, the receivers are the British Type 16 high impedance receivers

<i>Laboratory Reference Number</i>	<i>Type</i>
1	British B Leather helmet, with circular doughnuts and sorbo rubber covers over outside of receivers
7	British C (F) New type leather helmet with type (F) telephone holders, these holders have no rubber flange extending to the edge of the kapok doughnut
12	British E (G) Aertex helmet with type (G) telephone holders, in these holders a thick rubber flange extends from the edge of the receiver to the outside edge of the kapok doughnut
15	British D (G) Tropical khaki drill helmet with type (G) telephone holders
16	German Ln 26618 Leather, fleece lined helmet with no doughnuts, German receivers
17	US Navy Light leather helmet with "powder puff", R14 receivers
28	British C (G)—Loaded Similar to number 36, but embodying loaded rubber telephone holders. Total weight with receivers 592 gms

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- 31 U.S. Navy  
Leather helmet, chamois lined; Harvard design 5 earphone-cups; ANB-Hr receivers.
- 35 U.S. Navy—Tropical  
Khaki drill helmet, unlined; Harvard design 5 earphone-cups; ANB-Hr receivers.
- 36 British C (G)—Wired  
In the wired type of helmet the receiver leads are brought out to the back of the helmet and the microphone leads are brought to a plug at the side of the helmet. Total weight with receivers; 493 gms.
- 37 British Type C—Insulated Headband  
Adjustable headband fitted with Type C earphone-cups.

The accompanying graphs show the results of the attenuation measurements. Wherever possible the objective measurements for a given helmet are shown in comparison with the subjective measurements published by the Psycho-Acoustic Laboratory, Harvard.

One pair of helmets, Nos. 12 and 15, gave results which demonstrated the effect of "fit" upon attenuation. These helmets have identical earphone-cups and it is extremely unlikely that the materials of which they are made contribute appreciably to the attenuation. It is probable therefore that the noticeably greater attenuation afforded by helmet No. 12 is due to the better seal obtainable with this helmet. Although nominally of the same size, helmet No. 12 was slightly smaller than No. 15 with the result that the kapok rings were pressed more closely against the sides of the head.

In general it appears that the goodness of fit of the helmet has a very pronounced effect on the attenuation and that variations in the fit can easily mask the effects of change in the design of the earphone-cups. Where different types of helmets have to be compared it is most important, therefore, to ensure that the helmets should be as nearly as possible equal in size.

The following table shows the overall attenuation of the standard engine noise for each helmet.

TABLE II

<i>Helmet</i>	<i>Laboratory Reference Number</i>	<i>Attenuation db.</i>
British E (G)	12	17
" C (G) loaded	28	17
" C (F)	7	14
Type C headband	37	13
British D (G)	15	13
U.S. Harvard design 5	31	11
" " (drill)	5	10
British B	1	10
" C (G)	36	9
German	16	7
U.S. Navy (powder-puffs)	17	5



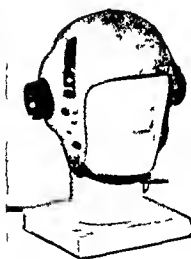
Dummy head



No 1



No 7



No 12



No 15



No 16





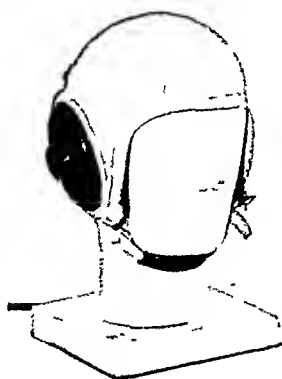
No. 17.



No. 28.



No. 31.



No. 35



No. 36.



No. 37.

# Measuring Attenuation of sound by Flying Helmets

In the following tables the attenuation measurements obtained by analysing the complex noise inside the helmets are given. Only three helmets were measured by this method. The third column in each table shows the difference between the attenuation values given by this method and by the pure tone method. A negative sign indicates that the value given by the pure tone method is the greater.

TABLE III

HELMET No 1			HELMET No 7		
Frequency	Attenuation	Difference	Frequency	Attenuation	Difference
c p s	db	db	c p s	db	db
100	7	-5	100	14	9
250	10	-2	250	11	-2
345	12	-3	345	16	0
620	13	-2	620	14	-2
960	28	-1	960	19	1
1800	47	10	1800	34	13
3270	43	1	3270	35	2
4780	58	10	4780	36	6
5915	46	3	5915	36	7
7540	57	-1	7540	32	2

HELMET No 36		
Frequency	Attenuation	Difference
c p s	db	db
100	6	4
250	6	-1
345	4	-4
620	11	2
960	16	-4
1800	48	2
3270	32	-7
4780	39	-6
5915	45	-2
7540	45	4

## 7 Comparison of Objective and Subjective Pure Tone Measurements

When the results of the objective attenuation measurements are compared with those obtained by the subjective method it can be seen that the two methods give attenuation curves which are similar in shape. The values of attenuation given by the objective method, however, tend to be consistently greater, especially in the middle frequency region. This difference is perhaps shown up more clearly by a comparison of the insulation indices calculated as described in the Harvard report\*. This

TABLE IV

Helmet	Laboratory Reference Number	Insulation Index	
		Objective	Harvard
British C (G) loaded	28	139	—
Harvard No 5	31	123	87
British B	1	111	84
British E (G)	12	107	67
Harvard No 5 drill	35	101	—
British C (G)	36	96	70
British D (G)	15	95	—
German	16	83	66
British C (F)	7	76	50
U S Navy	17	44	46

\* See "The Acoustic Design of Earphone Sockets for Helmets and Headsets" (Psycho-Acoustic Laboratory, Harvard University)

index is proportional to the area included between the attenuation curve and the frequency axis throughout the frequency band 250-4000 c.p.s.

The consistently higher values of insulation index given by the objective method are probably due to the good fit which is generally obtainable when using the dummy head. It is known that a faulty seal between the helmet and the head reduces the attenuation more particularly at the middle and the lower end of the frequency spectrum. This was borne out by experiments done in this laboratory in which small leaks were deliberately introduced between the helmet and the head. The effect of these was most considerable on frequencies below 2000 c.p.s.

It has been stated in Section 5.1 that the attenuation afforded by the helmets was measured three times at each frequency. The values thus obtained showed some variation which for the majority of cases did not exceed 5 db. at any particular frequency. Table V shows the range covered by these measurements for two helmets, (a) the helmet which showed the least variation out of those tested, and (b) the helmet which showed the greatest variation.

TABLE V.

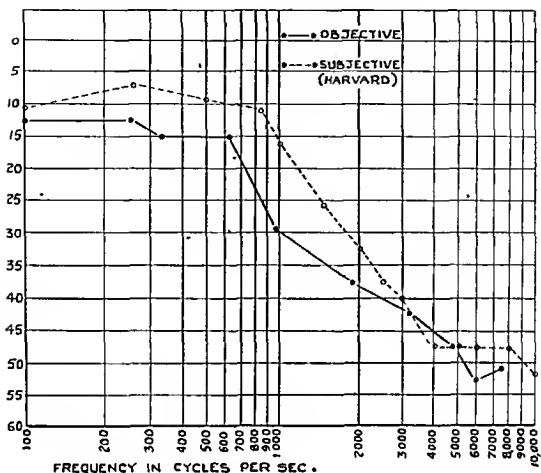
(a) Range	Frequency c p.s	(b) Range
0.5	100	5.5
0.0	250	3.5
0.5	345	5.0
3.0	620	5.0
2.0	960	4.0
1.0	1800	6.0
2.5	3270	4.0
1.0	4780	3.0
5.0	5985	2.0
5.0	7540	9.0

Statistical calculation shows that with such variations the difference between the mean attenuations for two helmets at any frequency is unlikely to be significant unless this difference is greater than 5 db. Significant is here taken to mean that the odds against such a difference being due to random sampling errors are greater than 20 to 1.

It is noticeable that the helmets which show least variation are those which are not provided with a kapok doughnut, for example the U.S. Navy powder-puff and the German helmet. This is no doubt partly due to the fact that these helmets in general offer a lower degree of protection and that the variation from measurement to measurement is therefore likely to be smaller, but it may also show that the acoustic seal provided by the kapok ring is more likely to vary according to the way in which the helmet is placed on the head.

As we have graded the helmets in order of merit on the basis of their insulation index it is important to know the minimum difference between the indices which we may assume to be significant. This minimum

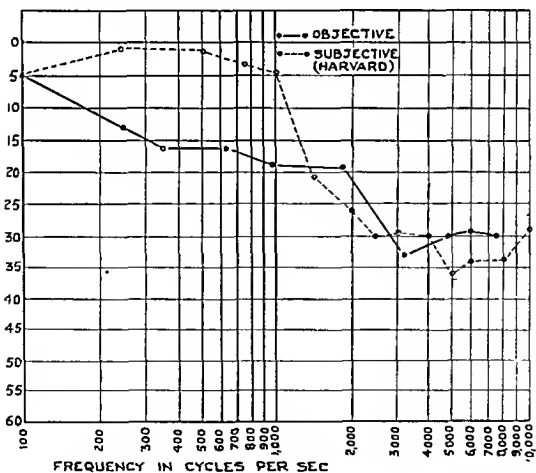
ATTENUATION IN DB

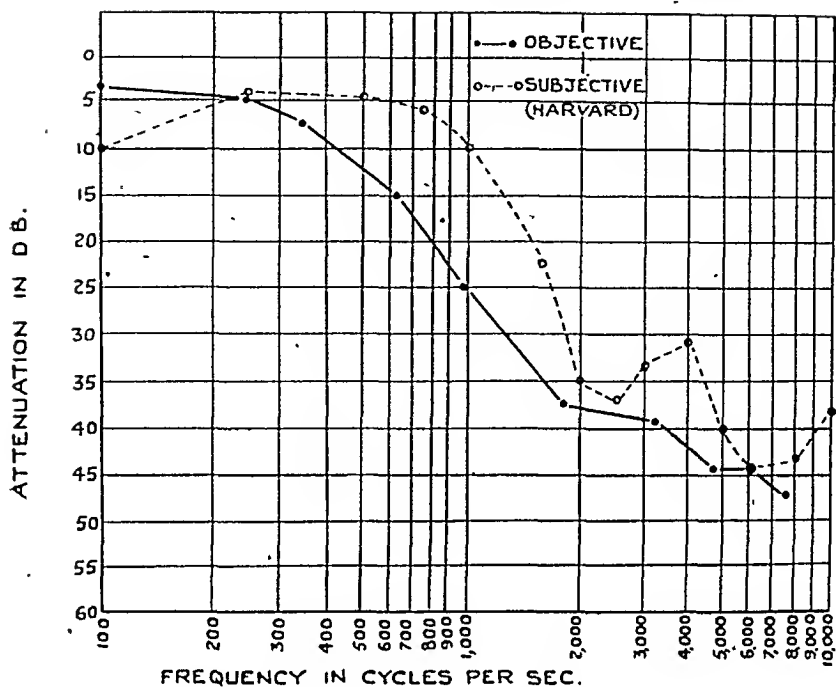


HELMET No 7

BRITISH TYPE C (F)

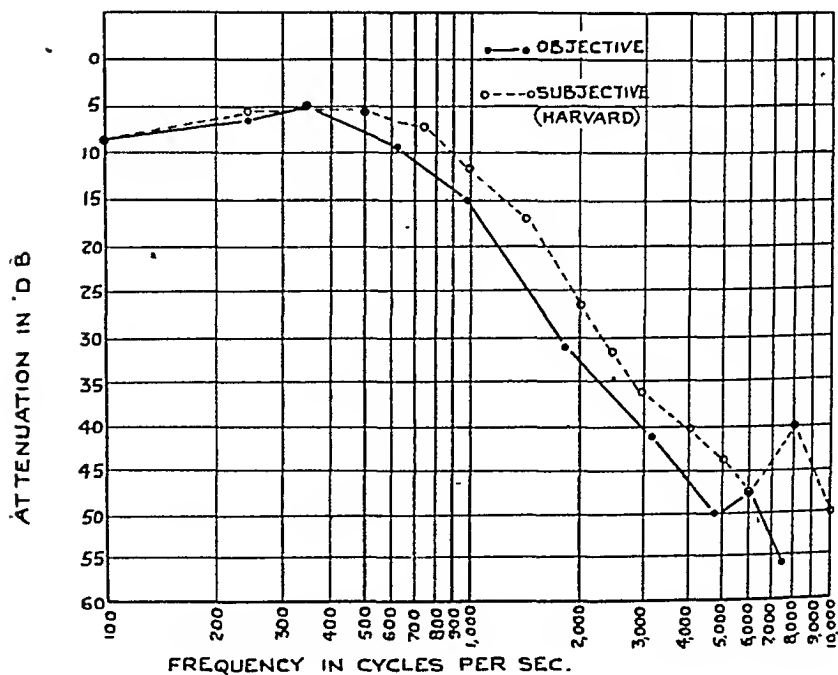
ATTENUATION IN DB



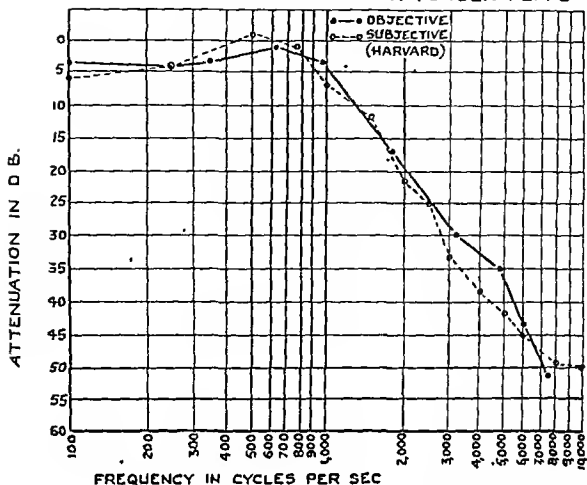


HELMET No 16.

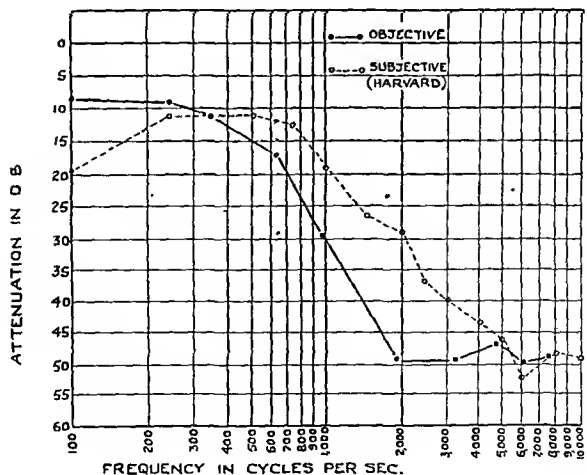
GERMAN.



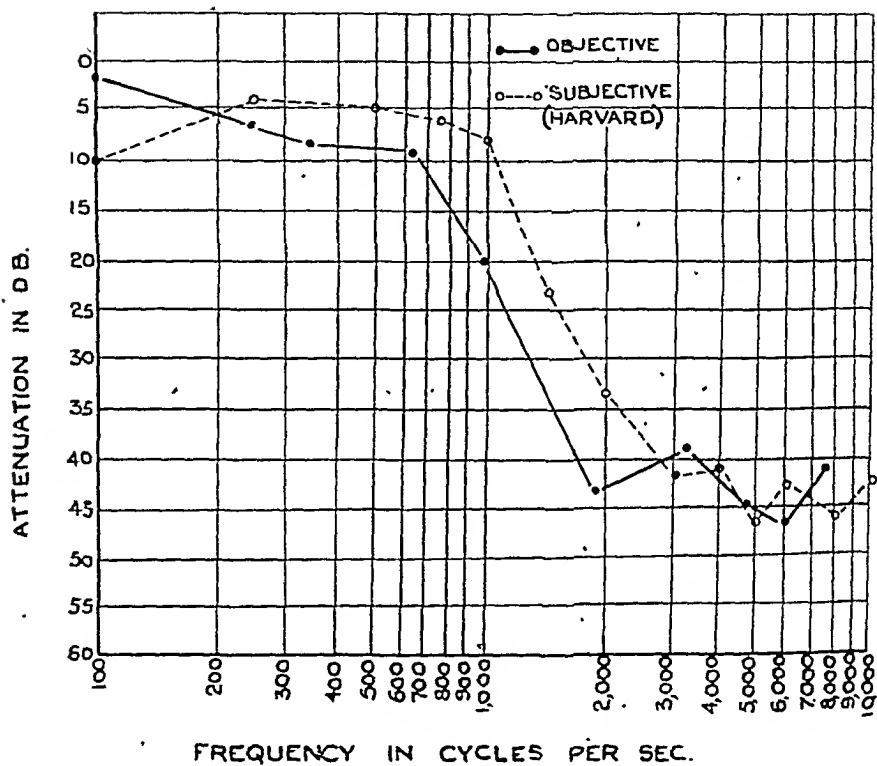
HELMET No 17. U.S. NAVY TYPE N A F 1092.  
WITH POWDER PUFFS



HELMET No 31. U.S. NAVY HARVARD DESIGN 5.

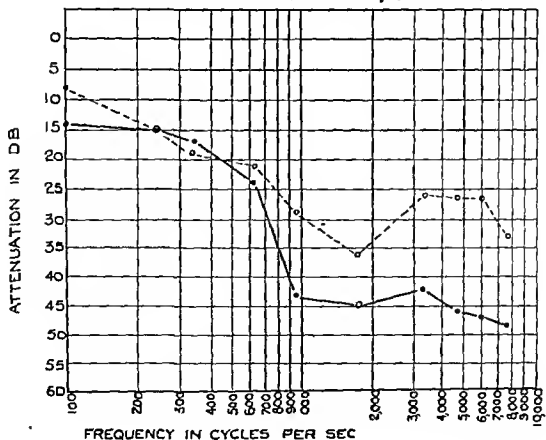
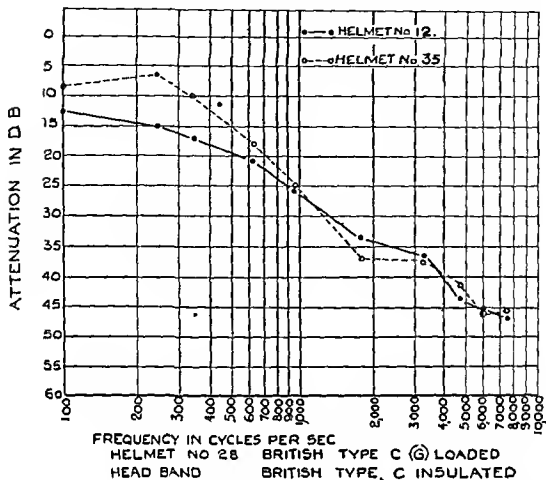


# HELMET No. 36. BRITISH TYPE C.(G)



HELMET No 12 BRITISH TYPE E (G)

HELMET No 35 U.S. NAVY HARVARD DESIGN 5 (DRILL)





difference has been estimated according to the standard statistical procedure for the two helmets listed in Table V. The insulation index was calculated for each set of attenuation measurements. This gave three indices distributed about a mean value. A simple calculation then gives the amount by which another mean must differ from this, assuming equal scatter in the individual values, in order that the difference should be significant. When this procedure was adopted for the two helmets which showed the greatest and the least variation in the individual values of attenuation it gave minimum differences of 11 and 4 respectively. This means that if every helmet showed as much variation in individual attenuation measurements as that listed in Table V (b), differences of less than 11 units in the insulation indices could not be considered significant while if they showed as little variation as that listed in Table V (a) the corresponding difference is 4 units. Most of the helmets which were tested show a variability more nearly equal to that of (a), so that in these circumstances we are justified in assuming that a difference of 6 units between two insulation indices represents significant difference in protection.

On this basis the grading of the helmets according to the objective method of measurement is as follows :

TABLE VI

<i>Helmet</i>	<i>Laboratory Reference Number</i>	<i>Insulation Index</i>	<i>Order of Merit</i>
British C (G), loaded	28	139	1
U.S. Navy, Harvard design 5	31	123	2
British B	1	111	
British E (G)	12	107	3
U.S. Navy, Harvard, drill	35	101	
British C (G)	36	98	4
British D (G)	15	98	
German	16	83	
British C (F)	7	78	5
U.S. Navy, powder-puff	17	44	6

# CONSIDERATIONS REGARDING THE SECONDARY AFTER-SENSATIONS CAUSED BY A STIMULATION OF THE SEMICIRCULAR CANAL SYSTEM

By L. B. W. JONGKEES and J. J. GROEN (Utrecht)\*

If a person on a rotating chair rotates with a constant angular velocity he will have no sensation of rotation. If the motion is suddenly stopped the test person immediately gets the feeling of rotating opposite to the original direction of rotation of the chair with a subjective angular velocity that decreases with time. When this sensation has passed, there arises after a short pause a feeling of rotation in the original direction of the motion of the chair, less intense though than the previous sensation. This cycle may be repeated a few times, each time after a little pause and usually with alternating direction (fig 1). The nystagmus under similar circumstances shows an entirely analogous behaviour.

Our knowledge of this process is mainly due to Fischer and his school, who accurately analysed the sensations of their test patients and thus discovered these rhythmic after sensations, by what they called "exact subjectivism", the analysis of sensations †.

In the process of after sensations there exists, however, an essential difference between the first after sensation and the following, secondary after sensations. Whereas the first after sensation can be explained in a purely mechanical way, according to the conception of Mach-Breuer, by the inertia which, after stopping the external movement causes a continued flow of the fluid in the canal the structure of the semicircular canals is such that the cupula as an oscillatory system is damped aperiodically and, therefore, cannot force such a sensation on to the mind by performing oscillations ‡. Besides this, many other arguments have been advanced

\* From the University Clinic for Diseases of the Ear, Nose and Throat, Utrecht (the Netherlands). Director Prof. Dr. A. A. J. van Egmond.

† M. H. Fischer and E. Wodak: Experimentelle Untersuchungen über Vestibularisreaktionen. *Z. f. H. u. O. Heilk.* 3, 198, 1922. C. Veits: Vestibularisreaktionen zur Drehprüfung. *Z. f. H. u. O. Heilk.* 29, 368, 1931. Zentr. bl. f. H. N. O. 17, 481, 1932. F. Woletz: Quantitative Untersuchungen über den postrotatorischen Nystagmus. *Z. f. H. N. O. Heilk.* 33, 476, 1933. E. Buys: Beitrag zum Studium der galvanischen Nystagmus. *Monatsschrift f. Ohrenheilk.* 43, 301, 1909. E. Buys and P. Rylant: *Arch. intern. de phys.* 49, 101, 1931.

‡ van Egmond, Jongkees and Groen: Quantitatieve onderzoeken over de geldigheid der opvatting van Mach-Breuer. *Stemhaushen. Ned. Tijds. v. Geneeskunde* 1943.

which tend to exclude the hypothesis that the secondary after-sensation may be caused by endolymph movement. Fischer and Wodak (l.c.) already pointed out that the plane in which the rotation is thought to take place, changes its position when the head is turned, but this change only occurs during the first after-sensation and not afterwards. According to Schmalz\* who has made excellent calculations with regard to the mechanical processes in the semicircular canals, the secondary after-effects must be caused centrally, because there is each time an interval between subsequent after-sensations. Veits indicates that later after-sensations never cause other sensations than a feeling of vectorial

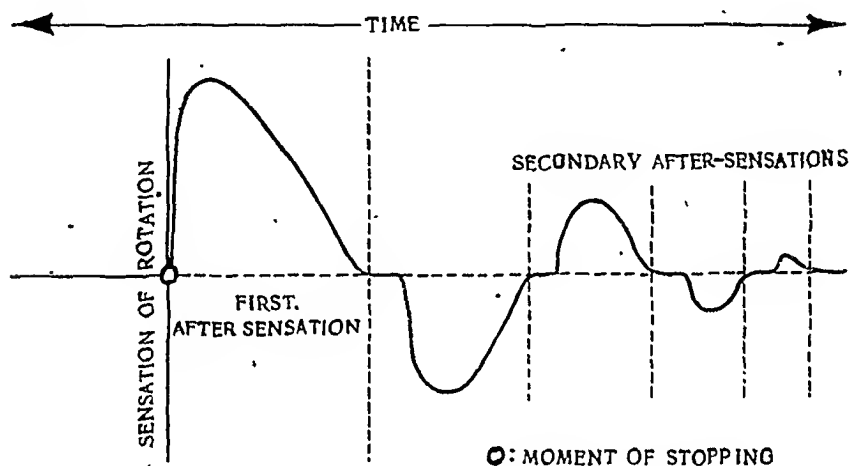


FIG. 1.

rotation and moreover, that the duration of the entire process of after-sensation may endure sometimes many minutes, which speaks against a peripheric origin.

Of course the greater part of the processes of after-sensation and after-nystagmus certainly occurs centrally. Nobody will doubt that the processes by which we become conscious of the sensation of rotation and the process resulting in the nystagmus mainly occur in the central nervous system.

However, none of the arguments presented to disprove a peripheric causation of this entire process is by any means conclusive. The opposite is true. Certainly the hypothesis can be excluded that the rhythmic after-sensations arise from oscillations of a periodically damped cupula. However, many other peripheric causes are conceivable, for instance chemical processes such as are known in the retina and are held responsible for the formation of after-images, electrical phenomena and finally

\* Schmalz. *Proc. Roy. Soc. Med.*, 25-1-1931.

## Secondary After-Sensations

phenomena of elastical hysteresis in the cupula, which is not only displaced after a deflection from the state of equilibrium, but of which the internal structure is also distorted. This process of recovery may, no doubt, last for several minutes and there is no reason why there might not be any pauses between successive phases of the after-sensations and the nystagmus. Also the fact that later after-sensations have not always alternating directions, but are sometimes observed in the same direction a few times in succession, may be readily understood from this standpoint.

The argument of Fischer and Wođak, that a change of the position of the head only causes a change of the subjective plane of rotation during the first after-sensation, needs further analysis. If the rotation took place in the plane of the horizontal canal, then the after sensation will occur in the same plane as soon as the rotation is stopped. This sensation is effected by a mechanical cause, namely a flow of the endolymph in the said canal. If the position of the head is changed at this moment then one has a sensation of rotation in another plane (disregarding the strong feeling of nausea and other sensations of motion such as inclination and counter-motion). This means that the sensation no longer originates only from the horizontal canal but also from other parts of the labyrinth. This is exactly what would be expected on mechanical grounds. The flowing fluid will tend to preserve its direction of motion and thus penetrate from the utricle into the vertical canals, causing a stimulus there. Experiments with a glass model have proved that such types of flow and whirl indeed occur. More extensive investigations on this subject are now being carried out.

A change of the position of the head during the later after-sensations causes no change of the subjective plane of rotation. Neither is there any mechanical reason that it should do so. There is no flow, hence there will be no stimulation of the nerves of the other canals. The nerve of the investigated canal remains stimulated in the same way, therefore the subjective sensation, the plane of rotation remains the same. So all these facts fit very well into a peripheric explanation of the origin of these phenomena and certainly contain no evidence in favour of a central origin.

From an investigation performed by one of us\* it appeared, moreover, that the first after-sensation lasts for a period of time which is proportional, up to a certain limit, to the logarithm of the magnitude of the impulse of deceleration. This limit is approximately  $60^\circ/\text{sec}$ . If one passes above this limit changes in the process appear to take place. The cupula is subjected to such large forces that its structure becomes distorted and thereafter, during a long period, changed values are observed. In case the stimulus has been much too strong, as for instance with our routine tests where the patients are subjected to impulses of  $180^\circ/\text{sec}$  or

\* Groen "De cupula als slingersysteem" *Ned Ver K N O artsen Mei 1944*

more, sometimes changes are permanent; the cupula leaks. Now it appears that secondary after-sensations only occur if such a deformation of the cupula is also effected, that is, if the impulse lies above  $60^\circ/\text{sec}$ .

So there occurs distortion of the cupula. This tends to recover, so that the cupula resumes its original form. If, after the return of the cupula to its zero position, the period of the first after-sensation has passed, then a stimulation of the nerve terminals in the cupula may still take place owing to elastic after effects within this member itself. From this standpoint it is, therefore, easy to explain, that the later after-sensations are not entirely equal to the first one with a real cupula deflection (vectorial rotation according to Veits), that no change of the subjective plane of rotation takes place when the position of the head is changed, and that pauses occur between subsequent after-sensations. All this, therefore, needs no central explanation.

But, whereas in the present case the central explanation was at least advanced on the basis of many real data, this happens frequently with processes where it has not yet been established by any means whether they do not occur mainly or even completely peripherically. And before the explanation of a process is consigned to this still so mystically veiled region which the sensory physiologist can by no means yet visualize clearly, thorough reasons should be present to reject a peripheric causation. Especially the solutions which are often at hand in this field, such as: "nervous disposition", "change in irritability" etc., yield no basis on which it may be hoped that experiments will permit a clarification of our insight. Therefore, the task of the sensory physiologist should be, to look within his own domain for a solution of the problems occurring; only if all possibilities have been exhausted he may reluctantly submit the problem to the brain physiologist or to the psychologist.

Thus, from our standpoint, even suggesting a central causation of certain phenomena when the peripheric possibilities are not yet completely exhausted, is quite objectionable, because every problem may seem to find a solution in this way and weak points of a theory are blurred. It is preferable to use a working hypothesis, being conscious of its insufficiency and its temporary character, rather than to see in the central approach to reality, owing to such blurring of weak points, the ultimate truth.

### Summary

A process of sensory physiology ought to be elaborated as far as possible in its peripheric, sensory aspects, before the difficulties may be referred to central processes. The process of secondary after-sensations after a rotation can entirely be explained peripherically, by assuming elastic after-effects in the structure of the cupula.

## CLINICAL RECORDS

### LARGE EXTRADURAL ABSCESS IN THE OCCIPITAL REGION SECONDARY TO MASTOIDITIS

By J W S LINDAHL (London)

EXTRADURAL abscess is a not uncommon complication of mastoid disease. The case to be described has, however, unusual features, firstly as regards the size and position of the abscess and secondly, in the mildness and misleading nature of the symptoms. The condition remained latent for several months and at no time after the initial and apparently mild otitis media were there any symptoms referable to the ear apart from slight deafness which sometimes persists after any attack of middle ear infection.

Unfortunately service conditions prevented my following the case through to complete recovery but, as interest lies in the diagnosis rather than the treatment, I think it justifiable to put it on record. The initial stages of the illness occurred abroad and no notes were available as to the patient's condition there. He was, however, an intelligent man and a good witness and I am satisfied as to the accuracy of his statements.

Craftsman A W, aged 33, was admitted to a Military Hospital on *April 27th, 1944*, complaining of pain in the back of the neck of  $3\frac{1}{2}$  months duration. The pain was present all the time and was localized to the right occipital region, spreading forward over the vertex, into the right temple and behind the right eye. It was not increased by movements of the head but he stated that he felt a "crunching" feeling in the neck on movement. On occasion he had felt as if he had a temperature but had never had any shivering attacks. Apart from the above he had no other complaints.

In *January, 1944*, while in the Middle East, he had what at the time appeared to be a mild attack of right sided otitis media following a cold. There was no actual earache but the right ear discharged, he had some pain on chewing, and was slightly deaf. He was admitted to hospital, the ear treated with dry mopping and spirit drops and the discharge cleared up completely in 10 days, leaving him with a very slightly diminished hearing acuity. He stated that he had no treatment with sulpha drugs and denied any previous history of aural disease.

During this time, however, he first noticed the pain in the back of the neck and this persisted after the otitis media had apparently resolved. Investigation of his nose, throat, teeth and eyes was made, his ears were examined and mastoids X rayed and he was told that the latter showed no abnormality. Finally a diagnosis of fibrositis of the neck was made, he was given radiant heat and discharged to duty after 28 days in hospital, improved but with slight pain still present.

He remained on duty with slight pain still present, and in *March, 1944*

returned to England with his unit. On the voyage the pain became more severe and, after disembarkation, he was admitted to an E.M.S. Hospital where the same diagnosis of fibrositis was made without, however, any investigation other than clinical examination. He was again discharged to duty after a short course of radiant heat which, however, produced no improvement and, on the day after his return to his unit, he again reported sick and was admitted to a Military Hospital under my care.

On examination he was a well built man with a rather sallow complexion and looked ill. Temperature 101°. Pulse 85. Tongue furred.

Movements of the head and neck were free and there was no rigidity but there was an area of tenderness about an inch square in the right occipital region just above the insertion of the occipital muscles.

Nose and throat were normal.

The left ear was normal.

The right ear showed a dry, intact drum which was not full or bulging. It was grey and thickened looking with a faint yellowish tinge and a little pink injection round the handle of the malleus. There was very slight deafness and the Rinne test was negative. There was no tenderness over any part of the mastoid or immediately behind it.

X-ray of cervical spine showed no abnormality. The temperature settled down completely in 48 hours but the pain persisted.

The possibility of a residual suppurative lesion connected with the ear was kept in mind but there seemed very little clinically to support this and the condition of the right ear could be considered to come within normal limits taking into account the fact that he had had an attack of otitis media. Examination by a physician revealed no cause for the symptoms either generally or in the central nervous system. The pyrexia noted on admission, however, suggested something more than fibrositis and we were fortunate that this occurred while under our observation as the rise in temperature was presumably intermittent and infrequent, and may not have occurred on the previous occasions he was in hospital.

A blood examination gave the following results:

White cells	15,000 with 89 per cent. polymorphs.
Hæmoglobin	90 per cent.
Sedimentation rate	72 m.m. in one hour.

X-ray of the mastoids showed opacity of the right side with loss of definition of the cell outlines.

Myringotomy on *May 8th* produced a little thick pus.

On *May 10th, 1944* the right mastoid was explored, a long posterior extension to the post-auricular incision being used. All cells were infected and, postero-superiorly, above the lateral sinus, a track was found which followed the lateral sinus for a short distance and then led upwards and backwards at an angle of 45° with the horizontal to terminate in a cavity lying 2 inches above and 1 inch lateral to the external occipital process, i.e. subjacent to the tender area already mentioned. The sinus and cavity contained about 3½ ounces of thick yellow pus. A thorough Schwartze's operation was performed on the mastoid, bone was removed from over the abscess cavity to leave it wide open, the wound was powdered with sulphonamide, left open and lightly plugged.

## Clinical Records

Culture of the pus showed organisms of the *Micrococcus catarrhalis* type only. In the opinion of the pathologist the original infecting organism had died out.

On the day following operation the occipital pain had gone and never recurred.

After five days on *May 15th* the wound was dressed under an anæsthetic and some more bone removed over the abscess cavity to lay it open more freely. After this the wound was lightly packed on alternate days.

Recovery was satisfactory but slow. There was some degree of anæmia and a transfusion of one pint of blood was given on two occasions *May 16th* and *27th*.

On *June 7th* the wound edges were freshened and secondary suture performed with excellent union except for a small triangular area over the mastoid which I was intending to graft.

Unfortunately, owing to the exigencies of the service the patient had to be transferred to another hospital.

When transferred on *June 12th 1944* he was very well and getting up daily. He had no symptoms whatever the wound was healed and the small granulating area was clean. The ear was dry and while there was a very slight degree of deafness, he could hear a whispered voice at 10 feet.

I think that a slightly earlier secondary suture might have resulted in complete healing and in this respect the after treatment was probably a little overcautious. He did however make a good recovery with sound healing and the risk of recurrence should be minimal.

I wish to thank Colonel H F Panton, D S O M C for permission to publish this case.



The results have been subjected to Statistical Analysis and it has been found that the results at 4000 cycles in the two series of cases are significantly different.

### Conclusion

1. There is a marked deterioration in the hearing for high tones especially at 4000 cycles in the ears of the soldiers. This is in accordance with a long known effect of acoustic trauma on the 4000 cycle band of the cochlea. It is of considerable interest to note that the deterioration is considerably greater in the Left ear than the Right.

2. Protection of the ears from noise has always been a difficult problem in the army, because the men must be able to hear orders given while actual firing is in progress. It is considered that the marked loss of hearing shown above in the left ear, makes the use of some form of protection a matter of great importance. It is suggested that if an adequate protection in the form of an efficient ear plug was provided for the left ear, and nothing used in the right, there would be no loss in the man's capacity to hear orders and the acoustic trauma of the left ear would be reduced to negligible proportions.

3. The use of an Audiometric method of examination is imperative in order that an accurate conception of the effects of acoustic trauma be obtained. The R.A.F. Gramophone Audiometer is an apparatus specially designed for rapidly testing a large number of people.

4. It is beyond the scope of this investigation to assess which of the many weapons used is responsible in the greater part for this acoustic trauma. Statements made by the men investigated in this series and from others, have given rise to the impression that the Rifle is the chief culprit. The trouble is caused usually by rifles fired nearby rather than by the man's own gun. The position adopted in firing a rifle is such as to leave the left ear very much more exposed than the right.

I am indebted to Wing Commander G. Bateman, to the Staff of the R.A.F. Acoustic laboratory for assistance in preparing this paper, and to Air Commodore E. D. Dickson for permission to publish it.

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## CLINICAL NOTE

### UREA A USEFUL AGENT IN THE TREATMENT OF SUPPURATIVE CONDITIONS OF THE EXTERNAL AUDITORY MEATUS AND NASAL VESTIBULE

By J L D WILLIAMS (Manchester)

UREA ( $\text{CO}(\text{NH}_2)_2$ ) is well enough known for its therapeutic action as a powerful diuretic when given by mouth, its effect being due to its property of retaining water on excretion from the kidney. This ability on the part of urea to absorb water has also led to its use as a local application in infected wounds<sup>1,2</sup>, indolent ulcers and allied conditions. In this connection, it is interesting to note that research into the action of urea on bacterial growth in cultures has shown that it has a definite effect, discouraging growth and causing modifications in form. The effects, however, were variable in different species of organism. In addition, urea is said to penetrate both animal and vegetable cells, dissolving proteins very easily<sup>3</sup>. These properties probably explain its beneficial effect in exudative conditions, and its power in separating adherent sloughs and membranes. Capillary proliferation has also been observed in tissues subjected to the influence of urea<sup>3</sup>.

Thus, to summarize the effects of urea when used locally, it may be said that its action is brought about by a combination of the following factors —

(1) Absorption and retention of water, (2) bacterial inhibition, (3) cellular penetration, (4) dissolving of proteins, (5) capillary proliferation.

Generally, urea has been combined with one of the sulphonamide group of drugs in the treatment of wounds and ulcers, and stress seems to have been laid on its antiseptic action rather than on the osmosis produced.

Interest in the use of the drug in otology has been confined chiefly to its action in chronic discharge from the middle ear, and it has been used for this condition in conjunction with most of the sulphonamides. It has also been tried along with Caroid, an enzyme extracted from the juice of the Papaw fruit (*carica papaya*) and having a proteolytic action over a wide range of temperature.<sup>4</sup> Reports of its use were frequent in the American literature prior to the World War, and varying success was obtained in chronic suppurative otitis media. Enthusiasm, however, seems to have waned, and in 1940 Seltzer, reporting cases of middle-ear infection in which urea was used, states that "a final evaluation suggests that urea in otology has no therapeutic value" and that it is merely "another one of those straws which are frequently grasped with the hope that at last an effective agent has been found for the successful treatment of chronic discharging ears".<sup>5</sup>

Unsuccessful as it may be in chronic otorrhœa, urea has a place in the otological pharmacopœia, and the purpose of this communication is to draw attention to an apparently little known application of the drug. Its action had

been noted on tropical ulcers, a feature of which is the tendency to form a hard and extremely adherent slough. Urea in crystal form was found to be one of the most efficient means of removing this slough, the effect being to liquefy it and render its removal, usually a matter of painful picking extending over a few days, a rapid and simple procedure. It was tried on furunculosis in various situations; and this writer can testify from first hand knowledge as a patient of its value in the removal of the hard core in this condition. The furuncle, often a small carbuncle, was surrounded with vaseline, leaving the point of the furuncle uncovered in the centre, somewhat like the crater of a volcano. This crater was then filled with urea crystals, covered with a dry dressing and left for twenty-four hours. At the end of this time, the slough was easily detached, leaving a healthy granulating surface.

The drug was tried in aural furunculosis, and quickly established itself as the treatment of choice in any but the mildest cases. The technique employed is as follows. The meatus is first mopped out with wool, and an effort made to find a chink through the swollen meatal walls in the severer cases. It is important to clear out as well as possible the space between the drumhead and the stenosed meatal area, paying particular attention to the anterior deep recess, as pointed out by Daggett.<sup>5</sup> No drug is a substitute for thorough toilet of the meatus in any exudative condition of the ear, and failure to carry it out properly must inevitably result in prolongation of infection, since an excellent culture medium, incubated at optimum temperature, is rapidly built up behind the swollen area of the meatus. Urea is then introduced on a gauze wick, dry for preference, the ribbon gauze being impregnated as well as possible with the crystals. It is sometimes difficult to get much urea to adhere to the dressing by this method alone, and usually it is necessary for an assistant to add a few crystals to the gauze as it is introduced into the meatal orifice. An alternative, particularly in a hypersensitive ear, is to use narrow vaseline gauze, the urea adhering more readily to it, and the introduction of the dressing being less disagreeable, since the vaseline acts as a lubricant. My impression is, however, that the urea is more efficacious in its "drawing" power if used dry, especially if the furuncles have begun to discharge. The dressings are repeated daily, preceded by careful toilet. A marked improvement is usually seen on removing the first dressing, subjectively as well as objectively. A dressing of any of the standard medicaments, properly applied, will usually produce relief of some degree in this condition, but a clinical test, using as controls mag. sulph. in glycerin, Ichthyol 10 per cent. in Glycerin and Aluminium acetate 8 per cent., has convinced the writer of the superiority of urea. The question of whether to incise a furuncle, always a debatable one since the incision may open up tissue spaces and spread the infection, has frequently arisen and has been avoided, in all but one case, by a vaseline wick plus urea. Once the swelling has subsided and the furuncles have ceased discharging, it is advisable to discontinue the use of urea, since continuation at this stage frequently causes rawness and tends to give rise to a troublesome diffuse meatitis. For this reason, it has been customary to use an astringent solution, on gauze wicks, for a further two or three days (e.g. alum. acet. 8 per cent.); in a considerable number of cases seen in the tropics, a residual infection with *B. pyocyaneus* necessitated dressings of acetic acid 1 per cent. for a few days. More recently, the urea treatment has

## Clinical Note

been followed by insufflating a thin film of Penicillin powder on to the meatal walls, which seemed a logical way of preventing an exacerbation of the Staphylococcal infection. The results of the above regimen have been uniformly satisfactory in what is, while not usually a serious illness, at least a most disagreeable experience.

Treatment based on the above principles has also been effective in several cases of furunculosis of the nasal vestibule. In one patient so treated, the swelling of the eyelids and forehead gave rise to the suspicion that one was dealing with a cavernous sinus thrombosis, but dressings of urea on vaseline gauze rapidly caused the furuncle in the vestibule to discharge and the swelling of the tissues drained by the angular vein to subside.

I should like to thank Mr Ian Fraser, D S O , O B E who informed me of the use of urea in ulcers and furunculosis generally, while in charge of the surgical division of a military hospital in West Africa.

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## SOCIETIES' PROCEEDINGS

### ROYAL SOCIETY OF MEDICINE—SECTION OF LARYNGOLOGY

February 1st, 1946

President—G. EWART MARTIN, F.R.C.S.Ed.

- (1) Squamous-celled Carcinoma of Left Cheek Treated by Operation;
- (2) Squamous-celled Carcinoma of Left Tonsil

By NORMAN PATTERSON

THE first of these cases was that of a man aged 76. He was seen at London Hospital in 1926 with squamous-celled carcinoma of left-cheek previously treated by Mr. Morris on two occasions by diathermy. Operation was carried out on December 29th, 1926, by flap method as described by the exhibitor in *British Journal of Surgery* (1937, xxv, 330). Recurrence took place in 1943 at old site but also involved the lower jaw. Operation was carried out again by means of flap method, September 3rd, 1943, at Royal Bucks. Hospital. Later bony sequestrum separated. Mr. Patterson showed drawings illustrating the method which he had devised many years ago. He added that the condition was commoner in men than in women, but in his short series there were more women than men (4 men and 6 women).

For the case-history in the second male patient, aged 68, he was indebted to Mr. Robert D. Owen who referred the case to him for treatment. Secondary glands on the affected side were removed at the London Hospital by block dissection in March, 1926. Three weeks later diathermy excision of squamous-celled carcinoma of left tonsil, anterior pillar, and base of tongue was carried out.

Both these cases were well, after twenty years.

THE PRESIDENT said that formerly dissection was practised in his hospital, but now practically all the cases had been handed over to the radiologist for deep X-rays.

A. J. M. WRIGHT said that in Bristol they were not accustomed to send all these cases to the radiologist. If he himself had a carcinoma in the cheek he would not have the slightest hesitation in choosing somebody to deal with it by diathermy rather than by radiation.

E. D. D. DAVIS said that it had been his experience that these tumours, treated by means of deep X-rays, died from secondary growths within eighteen months. Personally he preferred diathermy.

# Royal Society of Medicine

## Mixed Salivary Gland Tumour in Palate

By R R SIMPSON

F B, male, aged 38

September 1945 Swelling right parotid, size of an orange, and swelling of right half of palate, size of a tangerine orange Palatal swelling bulges forwards and downwards and beyond mid-line causing some difficulty in chewing and swallowing

Both swellings considered to be part of same tumour and of the mixed salivary type

Mr Simpson said that this large tumour had been present for several years. He first saw the patient in 1938, when the tumour was about half its present size Should the tumour be treated by operation or should it be left entirely alone?

C P WILSON said that he did not think there was any doubt but that such cases were malignant The consensus of opinion was that they were low-grade carcinomata

If the tumour in the palate was causing trouble there was no reason why it should not be excised The most satisfactory treatment seemed to be to treat these tumours with radiotherapy and excise them afterwards

About a year ago he showed a patient in whom a tumour of this type in the peritonsillar region had been excised in 1922 Since that time he had had two or three further tumours in the parotid with recurrences, and had had excision and several courses of radiotherapy Three years ago he developed a swelling of the ilium, which on exploration was also found to be of the same pathology The patient was still working after twenty-four years, although he had a facial palsy on the affected side, and would probably show a further recurrence later

MUSGRAVE WOODMAN said that the principle which should be followed was to remove these tumours whenever they could be removed He was certain that they were malignant, although the malignancy was of low grade They could be safely removed from the palate When they occurred in the parotid it was wiser to leave them alone He thought that they did recede to a certain extent under radium and X-rays One patient whom he saw was a commercial traveller who had a large tumour which had been under observation for ten years He did not want an operation because he was afraid that it would damage his voice and so handicap him in his business He was treated by means of X rays He was still alive, but the tumour was rather larger than formerly though it had not increased to any great extent

E D D DAVIS said that in his experience X ray and radium treatment had no beneficial effect on these tumours It made a subsequent dissection operation much more difficult

## Boeck's Sarcoidosis with Nasal Lesion

By F C W CAPPS and J C HOGG

Male, aged 21 August 1945 attended King George's Hospital, Ilford, with a history of nasal obstruction for eighteen months, swelling of cervical glands, and an intermittent swelling of proximal phalanx of right middle finger There was nodular infiltration of the nasal mucosa, redness and dryness of the pharynx,

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and many discrete rubbery glands on both sides of the neck. W. R. and Kahn were negative. W.B.C. 11,400 per c.mm.

X-ray of finger : "Upper half of medullary cavity has lost its outline when compared with other phalanges".

Histology of the nasal lesion : A fibrolympho-angioma was suggested, but the pathologist admitted that he had seen nothing like it before. A section was stained for tubercle bacilli, but none was found.

In December 1945 the patient was seen at St. Bartholomew's Hospital. Clinical picture was substantially the same, but enlarged glands were also found in the left axilla. There was no enlargement of the spleen, and there were no inguinal glands. The radiograph of the chest showed increased hilar shadows suggesting glandular enlargement. Boeck's sarcoidosis was diagnosed. Nodule from nose was inoculated into a guinea-pig, but the guinea-pig unfortunately died of pneumonia the day following. Gland was removed for section and the report was : "Node almost entirely replaced by a mass of pathological tubercles packed closely together. Giant cells are very sparse, but fibrosis is considerable. A few areas of early hyaline degeneration but no caseation. No tubercle bacilli seen".

The histological picture strongly favoured a diagnosis of Boeck's sarcoidosis. The patient was fit and well and there were no other obvious lesions in the upper respiratory tract. The tonsils had been removed.

This was shown as a rare condition of which not many cases were seen. There was some doubt as to the diagnosis at first, but it had been confirmed on histological grounds. There was a strong presumptive evidence of sarcoidosis. Mr. Hogg asked for suggestions as to any form of treatment which might improve the condition. The patient had a very poor airway, and it was of this he chiefly complained.

E. D. D. DAVIS said that clinically this condition looked like a tuberculoma, but Mr. Hogg had told them there was no ulceration. The nodules did not break down and ulcerate. Lupus was a very chronic disease and continued for many years. The section had a different appearance from that found in common lupus.

J. H. OTTY said that a number of these cases were seen up North but he looked upon this as a case of tuberculoma of the nasal mucosa and these cases, as a rule, did not ulcerate. He did not think he had seen lupus within the nose without lupus of the cheek or elsewhere in the skin of the face. He had treated them with light diathermy.

### Tumour of Nasal Septum (Chondrosarcoma). Operation and Recurrence

By ROBERT D. OWEN

H.J.W., male, aged 43. First seen in September 1943, when he complained of complete nasal obstruction of long standing. Examination showed a red smooth mass arising from the nasal septum and causing complete occlusion of both posterior nares. X-rays showed the right antrum diffusely opaque, with a rounded opacity extending into the left antrum. An exploratory operation

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was performed, with right lateral rhinotomy approach, and the whole of the nasal septum, with the mass, was removed. The pathological report showed the mass to be composed mainly of chondromatous tissue, but suggestive of chondrosarcoma. In November 1944 another operation was performed for a recurrence involving the floor of the right frontal sinus, extending down to the inner canthus, also in the roof of the mouth in the mid-line. Further sections showed a similar chondromatous structure. It was difficult to judge the malignancy on histological grounds, but the tumour was evidently forming metastases. Opinion varied as to whether any response could be produced by teluradium, and the problem was how far further surgical interference could be carried out. The man's present condition showed further recurrences, particularly in both orbits.

The pathological report showed that two of the sections, namely, those of tissue from the canine fossa and from the left ethmoidal region, consisted mainly of chondromatous tissue. It was difficult to decide from the histological appearance whether it was a simple recurrent chondroma or a chondrosarcoma, but from the way it appeared to be destroying the tissues it was probably the latter. Another section, probably fibrous tissue from the antrum, showed, in one part of it, some chondromatous infiltration. The tumour was avascular. He asked for suggestions from the Section as to whether surgery was the best line of treatment or whether radiation in one form or another could be introduced.

GAVIN YOUNG said that he had at the moment two of these cases. He was assured by the radiotherapist that they were not radio-sensitive, and it had been customary to deal with recurrences as they occurred, by diathermy.

### Chondroma

By W. STIRK ADAMS

A man, aged 22, in September 1933 came under the care of Mr Holt Diggle at the Christie Hospital, Manchester, suffering from a swelling in the left side of the face, which on surgical exposure proved to be an ossifying chondroma with no evidence of malignancy. The tumour was excised and radium inserted into the cavity of the antrum. From then he remained well until October 1936, when a left orbital swelling occurred, but subsided. This returned in 1938 and, in November, an external operation was carried out for removal of the tumour. Three years later he was referred to Mr. Stirk Adams. At this time there was a firm fullness in his left cheek and inspection of his nasal cavity showed a mass which had extended through the nasal septum and was pressing on the lateral nasal wall on the right side. A sub-labial excision of the mass was undertaken and he remained well until March 1943, when a further operation was carried out because of increasing trismus. The neoplasm had by this time extended posteriorly into the sphenomaxillary fossa. A further partial removal was carried out in the following November, in an attempt to relieve his spasm, and at this time the mass was found to have extended into the basiocciput and the basisphenoid. In April and October 1943, courses of deep X-rays were attempted but could not be tolerated. Biopsy material removed



at operations was examined and in every case Professor Haswell Wilson reported a simple chondroma with no evidence of malignancy. The prominent symptom, apart from that of the local lesion was a devastating continuous pain in his face and head, and several of the operations were carried out because, after operation, he obtained relief from this pain for weeks or months. The last attempt to relieve him was carried out in May 1944. He died of increasing weakness but without evidence of somatic secondaries, in November 1944, eleven years after his first symptom.

It was unwise, therefore, to regard any chondroma developing in the nasal capsule as innocent.

LIONEL COLLEDGE considered it very unlikely that the tumour was radio-sensitive. He thought it most undesirable to make incisions in the face, they were disfiguring, and they were not necessary from the point of view of obtaining increased exposure. The customary procedure in what was called Rouge's operation gave all the exposure required.

## Laryngeal Granuloma following Intratracheal Anæsthesia

BY IAN G. ROBIN

Woman, aged 50. Two years ago she had two gynaecological operations both under an anæsthetic. She complained of hoarseness immediately afterwards and ever since. He brought forward the case rather as a supplement to the Presidential Address (Ewart Martin, *J. Laryng.*, in press). Three months ago there was definite granuloma. He thought there was now a small granuloma on the other side, perhaps due to a recent attack of influenza.

THE PRESIDENT said that he had seen three further cases since those previously reported by him. One of these very much resembled the present case. It was difficult to see why a tube passing into the larynx could give rise to a granuloma in one case and not in hundreds of others.

I. SIMSON HALL said that the number of cases of this form of laryngeal irritation seen was extremely small when the large number of anæsthetics carried out every day in all parts of the country was considered. He suggested that there must be some predisposing cause apart from the trauma of passing the tube. As a possible suggestion of this causation it was noteworthy that fibroma or granuloma of the cord was most liable to form when the voice was used excessively in the presence of slight inflammation. It was possible that slight laryngeal inflammation or slight cold might be a predisposing cause of the granuloma formation following intubation.

C. P. WILSON said that he had seen a case in which a granuloma of the larynx had occurred as a result of an intratracheal tube having been left in the larynx for a week. The nurse in charge of the patient had removed the metal connection of the tube from the nose without realizing that it was attached to the intratracheal rubber tube. The patient had complained of no discomfort other than loss of voice, and it was not until the surgeon had gone down to the country and examined the patient a week later, that it was discovered that the tube was still in position. In this case the granuloma must have been due to trauma.

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J. H. OTTY said that he had only seen one such case in Aberdeen in the last fifteen years. He supported Mr. Hall's contention that infection might play a part as the only case in Aberdeen followed a bronchoscopy for bronchiectasis.

R. D. OWEN said that he thought the practice of passing the tube down blindly under pentothal anaesthesia only, was to be deprecated.



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## PACCHIONIC GRANULATIONS AND BRAIN HERNIAE

By P. G. GERLINGS (Amsterdam)\*

THE Pacchionic granulations consist of arachnoideal flocks, separated by a thin endothelial dura-layer and connected with an intradural blood sinus. The Pacchionic granulations have a special function to perform, i.e. to influence the brain pressure, disturbances can lead to an increased intracranial pressure as in some cases of otogenic hydrocephalus

An arachnoideal flock originally consists in a substantial meshwork of connective tissue covered with several layers of endothelium. As the granulations enlarge they cause spaces in the meshwork of connective tissue which communicate with the subarachnoid spaces and contain the cerebrospinal fluid. The endothelium often becomes stratified

The Pacchionic granulations are especially found in the roof of the skull in connection with the superior longitudinal sinus, but also at the base of the skull. The predilection site is the pyramid-apex, chiefly the cavum Meckelii because an extensive venous plexus is present here, communicating both with the sinus petrosus superior and inferior and sinus cavernosus and with the plexus venosus caroticus and the venae meningeae mediae. Ruttin points also to the sinus petrosquamosus, in text-books of anatomy described as a variety, which, however, is found almost without exception on microscopic examination, somewhat laterally to the canalis musculotubarius. It is a sinus consisting of several spaces typus cavernosus sinus. Sometimes this sinus receives the sinus petrosus superficialis (Ruttin) which runs above the sulcus of the Nervus petrosus superficialis major and can be followed retrogradually to the hiatus canalis facialis. In this extensive region of venous sinuses Pacchionic granulations are especially found. Very rarely Pacchionic granulations

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are found in the posterior cranial fossa near the sinus transversus (Brunner). Sometimes accumulations of endothelial cells, so-called "endothelial tracts" ("Solide Endothelstränge"), first described by M. B. Schmidt, are found in the dura. These accumulations emerge from Pacchionic granulations and are perhaps of importance for the development of sarcomata and psammoma of the dura (Cushing).

In 1870, at a Meeting at Würzburg, Recklinghausen demonstrated a specimen of a brain tumor, obtained at an autopsy, which showed numerous brain herniae. Brain herniae are bulbous protrusions of brain tissue in the dura mater; later Beneke and Blasius demonstrated that brain herniae always develop *in* Pacchionic granulations. Consequently brain herniae are Pacchionic granulations which are filled with brain tissue instead of cerebrospinal fluid. Recklinghausen had already pointed to the increased brain pressure as of etiological moment and it can easily be understood that thus brain tissue can be embedded in a Pacchionic granulation.

In a number of cases an increased brain pressure is absent, so that Wojno speaks of "physiological brain herniae". Others (Erdheim, Cushing) think that a temporarily increased cranial pressure is necessary for some time in a former period of life. According to Brunner, however, these brain herniae should occur more often than is now the case. Wojno assumes congenital pia defects causing a predisposition for brain herniae. The finding of Ruttin, i.e. brain herniae in six temporal bones of three children with florid rachitis (age 2-4 years) is very important as this is rarely found at an early age. A further explanation of the connection between rachitis and brain herniae has not yet been found. Erdheim (Neurological Institute, Vienna) made an extensive investigation about the structure of brain herniae. Different steps can be distinguished, dependent on the development of the brain herniae in the Pacchionic granulations. During its development the brain hernia glides along the pedicle of the Pacchionic granulation, pushing it aside, simultaneously compressing the blood sinus. As the brain herniae enlarge they cause an increased pressure on the surroundings, by which atrophy of the Pacchionic granulations and pushing aside of the blood sinus occurs. In the long run the whole intradural cavity is filled with brain tissue which remains in communication with the brain via the aperture in the inner sheath of the dura, the so-called operculum (Erdheim). It is also possible that a hernia retracts itself *via* this aperture in the operculum (Cushing).

Continuation of the brain pressure causes erosion of the bone of the base of the skull, the so-called "Delle". Very seldom a brain hernia is found extradurally.

Brain herniae are almost exclusively found at the base of the skull, at the same predilection sites of the Pacchionic granulations. On removal of the brain small rests of brain cortex are severed which were

# Pacchionic Granulations and Brain Herniae

sticking to the dura. If the dura is severed from the base of the skull, small rests of cerebral cortex, pin point sized, of weak consistence and gray-red colour, are found together, separated by connective tissue, so-called colonies of brain herniae. The varying microscopic picture of the brain herniae is caused by secondary changes in the brain tissue on the one side by pressure and on the other side by vascular disturbances. The latter are caused by pressure of the supplying vessels in the aperture of the operculum. Beside typical brain tissue with beautiful ganglion cells, all sorts of transition to glia tissue without any structure, with oedema, hæmorrhages, sometimes inflammatory infiltration, are found. In the "physiological brain herniae" of Wojno inflammatory symptoms are absent. In 51 cases of 225 autopsies Franz found brain herniae, the youngest case being three years of age. Podesta examined 29 temporal bones. Pacchionic granulations were 12 x found in the neighbourhood of the pyramidal apex. Rutin examined 50 series of temporal bones of adults with various pathological processes, except brain tumors. Sometimes he found Pacchionic granulations, once a brain hernia. In this case in the marrow cavities of the pyramidal apex symptoms of a cured rachitis could still be found. In 10 cases of brain tumor Brunner found 5 brain herniae at the base of the skull.

The investigation of Erdheim drew the attention of Viennese otologists to Pacchionic granulations and brain herniae of the temporal bone. O. Mayer was the first who pointed to their pathological importance, i.e. when Pacchionic granulations and brain herniae are found in the tegmen tympani, the roof of the Eustachian tube or communicate with the sinus transversus. Brain herniae are also found in connection with pneumatic cells (Mayer, Brunner), marrow cavities (Kecht, Podesta), facial canal.

## Description of the Specimens in Two Cases

*Case I.* Patient suffering from gargoylism (Hurler's disease). This disease is characterized by osteodystrophy and enlarged spleen and liver. They are very ugly children, who by dwarfism, heavy build, heavily crooked bones, are much alike. The joints cannot be extended. Gargoylism is classified among the lipoidoses.

In the left middle cranial fossa numerous impressions are found into which the dura mater proceeds (Fig. 1). In the latter, cavities filled with blood and communicating with the vessels of the dura, are often found. The bone contour of these impressions is partly irregular, no symptoms of new bone formation or bone destruction. In the deeper bone layers perivascular bone resorption does occur. In several places Pacchionic granulations (Fig. 2) are found. The pedicle of the Pacchionic granulation penetrates through an aperture in the inner sheath of the dura to the intradural blood spaces. The size of the

Pacchionic granulations varies. The structure can easily be seen with a high power photomicrograph (Fig. 3), here and there accumulations of endothelial cells being seen. One large dehiscence is found in the tegmen tympani (Fig. 4), surrounded by several impressions. Through this dehiscence a large Pacchionic granulation penetrates into the epitympanic cavity of the middle ear. The Pacchionic granulation is separated by a thin dural layer and mucous membrane from the proper tympanic cavity. The course of the pedicle, penetrating into the inner sheath of the dura through a fairly large aperture, can clearly be followed (Fig. 5). One large brain hernia (Fig. 6) is seen together with a Pacchionic granulation, but separated from it by a dural septum. In a dense network of glia tissue numerous well-coloured nuclei of varying form among which ganglion cells are found. The Pacchionic granulations and brain herniae are exceptionally found on the left side, although in the right middle cranial fossa some impressions are found.

*Case II.* Patient, female, 50 years of age, died of subacute pneumococcus meningitis, in which the infection reached the dura of the middle cranial fossa *via* a spontaneous dehiscence of the tegmen tympani. In this case Pacchionic granulations and brain herniae were of no pathological importance. On the left side some Pacchionic granulations are found in the middle cranial fossa and one larger brain hernia in a larger impression near the oval window. The pedicle of the hernia is very broad, so that a large aperture in the operculum is found (Fig. 7).

This brain hernia developed in a Pacchionic granulation which had been pushed to the side. Also a small blood cavity can still be seen. The structure of the brain hernia is less distinct than in *Case I*, especially the colouring of the nuclei is moderate. In the facial canal (Fig. 8) a blood cavity is found, protruding into the dura, here a Pacchionic granulation and a so-called "Endothelial tract" of Schmidt are seen.

The pathological importance of brain herniae consists in the fact that they can conduct an otogenic infection, especially cases in which the infection proceeds through the tegmen tympani or pyramidal apex. Only in Podesta's case the infection proceeded through the petrous angle to the sinus transversus.

During the mastoid operation, when laying free the dura in the neighbourhood of the tegmen tympani and in front of it, a Pacchionic granulation or brain hernia may tear off. Through the dural fistula, occurring by this, an inflammatory process can quickly give rise to a leptomeningitis.

It is well to remember that in cases of meningitis a secondary infection is possible from the meninges. An infiltration in the brain herniae, even suppuration, can develop without them having played a rôle in the infectious process.

In the literature the following cases are found :

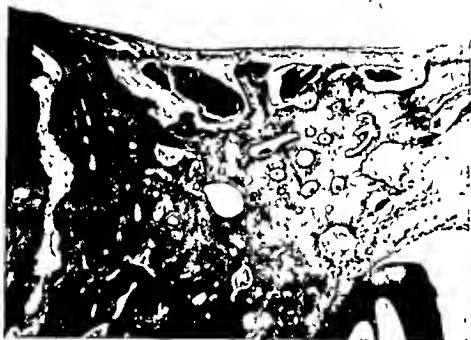


FIG 1

Intra-dural blood-sinus in impressions of the middle cranial fossa



FIG 2

Pacchionic granulation





FIG. 3.  
Pacchionic granulation (large magnification).



FIG. 4.  
Dehiscence of the tegmen tympani with large Pacchionic granulation  
in the epitympanic cavity.



FIG 5

Pedicle of the Pacchionian granulation in the aperture (↖) of the operculum



FIG 6

Brain hernia

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intense opacity of the left maxillary sinus, corroborating our doubts to be dealing with an intrasinus hæmorrhage. Ice is applied to it. A roentgenogram is taken the following morning, showing complete although not uniform opacity of the left sinus (Roentgenogram 1). Just inside the vestibulum nasi, partly adherent to the mucosa in Kiesselbach's area, there are some bloody crusts which are easily removed with forceps. The patient is requested to blow his nose in order to free it from secretions, and an abundant hæmorrhage takes place during which an attempt is made to discover its origin, although unsuccessfully. The careful scrutiny with the aid of the aspirator, gives a negative result. Within five or ten minutes, the hæmorrhage ceases spontaneously and suddenly. During the time of bleeding, it was not possible to see blood in the middle meatus, because it is not itself well visualized. A puncture of the left maxillary sinus was made, withdrawing two or three small black clots by means of a syringe. Puncture has been absolutely non-traumatic with the puncture-needle we use, without provoking the least bleeding. The washing done afterwards, let several old large dark clots come out. No fresh blood is to be seen. Before withdrawing the needle, we injected 1 c.c. of a 3 per cent. ephedrine solution into the sinus.

The ear drum has partly changed its primary bluish colour. In the upper portion, it presents its normal aspect, but in its inferior portion is seen through transparency a bluish deposit, which we believe to be blood, occupying at least a third of the total corresponding surface.

Immediately after the washing, we sent the patient over to Dr. Berti, who took a new roentgenogram in which we see that the sinus has cleared very much, although maintaining a thickened mucosal image, despite the probable effect of ephedrine injected into the sinus (Roentgenogram 2).

Six hours later, the patient's condition is excellent. Subjectively he feels well and thinks he is quite restored. There is no pain or malar heaviness. He is less deaf. Audiometric tests are checked by the tuning forks, being quite within normal limits.

On the next day, the patient hears well. No deposit is to be found in his ear. The nares are absolutely free.

The sudden improvement that came after the blood clots were removed by washing, increased on the following days. Hæmorrhage did not occur again notwithstanding the patient being submitted to a new puncture with a 4 mm. trocar, in order to perform antroscopy. This however, failed owing to a faulty antroscope.

On the following days, there was no nasal trouble, except a slight degree of obstruction, probably referable to the trauma caused by packing and the antroscopy.

### *Study of the blood.*

Red blood cell count 3,750,000.      Hæmoglobin 63.      Colour index 0.84.  
Anisocytosis - Poikilocytosis.  
White blood cells 4,000.  
Bleeding and coagulation time · normal.

## Epistaxis of Sinusal Origin

In the presence of a patient, who bleeds from his nose, what should be our reason for thinking that the hæmorrhage has its source within the sinus?

First of all, *the difficulty of finding the bleeding point*. When it is an anterior hæmorrhage, which originates commonly in the vascular area, the problem is simple and presents no difficulties. Sometimes, it is possible to see the beating of the bleeding vessel, and if hæmorrhage has been already controlled, it is enough to tampon with an adrenaline soaked pack, to clearly visualize the vascular area, making it easy to identify it. On the other hand, if a negative result is obtained from the examination of this usual bleeding area, things are quite different.

If the nose is examined the very moment it bleeds, it is very hard to identify the blood vessel, most of all, if the hæmorrhage is abundant, such as is generally the case. The blood overflows the field, chokes the patient and vision becomes difficult, if not impossible, being necessary at times to postpone every manipulation and wait for a spontaneous arrest. It is in this that we can see the usefulness of the aspirator, whose employment makes a minute survey possible. We must do our utmost *to observe with care the middle meatus*, to see if blood comes down from there, flowing over the inner surface of the inferior turbinate. This verification is conclusive, leaving no room for doubt.

But, if the patient comes to us with his hæmorrhage arrested, it is difficult to say, where it came from. Questioning will provide some data. Among these, a very important one, is the *abruptness of the beginning* and of the bleeding arrest. It is after this fashion, it happened in our patient, and to which Hall and Thomas's special attention is devoted. Hæmorrhage stops and reappears abruptly and suddenly, with no apparent cause whatever, being abundant from its very start. The authors we have just mentioned, suggest that this characteristic should be attributed to a clot obstructing the ostium. At certain times, the blood coming out, overcomes the opposition made by this occluding clot, and bleeding occurs again. An energetic negative pressure applied to the nose, with the purpose of provoking hæmorrhage, failed. In our case, on the contrary, hæmorrhage was precisely due to a forced expiration, blowing of the nose, in such a way that it could be compared to turning the tap of a pressure water-pipe. Perhaps, the positive pressure provoked by this manœuvre had displaced a clot stopped in the ostium, but we don't think it able enough to reproduce in such a way a hæmorrhage that had ceased several hours before, unless the offending blood-vessel had been in direct contact with the occluding clot. In fact, we think that the repetition of hæmorrhage, may be due rather to the movement of the small blood clot—occluding the bleeding vessel. The act of blowing the nose, on introducing air by pressure in the interior of the sinus, has set in motion the clot content within it, being this same clot content that keeps direct

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contact with the vessel that bleeds and with the clot formed in the vascular lesion. The setting in motion of these intrasinus clots by the blowing of the nose, would be the cause of the repetition of the hæmorrhage by its direct action on the affected vessel.

The arrest of hæmorrhage comes of a sudden. This arrest may be due to these two mechanisms: the clot in the ostium or the pressure exerted by the clots within the sinus on the bleeding vessel.

Hall and Thomas also describe as typical of these sinusal hæmorrhages an *intense pain, located in the inner angle of the eye*, present above all while the hæmorrhage lasts. In our own patient, we have recorded the presence of a painful steady sensation although of slight intensity, which could be compared rather to a feeling of heaviness in the malar region. Thus there occurs, in both instances, the presence of the symptom, differing only in the degree of intensity.

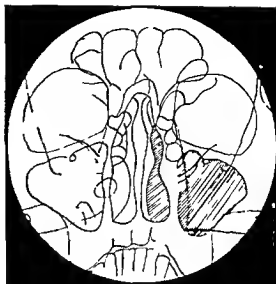
None of the authors we have just mentioned, has been able to find general causes, to which one could ascribe the hæmorrhage. Normal blood pressure, normal coagulation time, etc. These negative data corroborate the opinion that epistaxis of sinusal origin does not constitute a special entity, but that they take place spontaneously as those of the nose, the same predisposing or determining factors such as: season of the year—temperature, barometrical pressure, etc. Stutz.<sup>7</sup>

The roentgenographic study has revealed an obvious opacity of the affected sinus, in all the cases. Diaphanoscopy was complementarily carried out in some of them. In our patient, the degree of opacity revealed by diaphanoscopy was such as to arrest one's attention.

Interpretation differed with the authors mentioned with regard to the opacity revealed by the x-rays study. Our serial roentgenograms, taken before and immediately after the removal of the content of the sinus, are very illustrative. One can see in them, that the intensity of the shadow is due, in its greater part, to the clots within the sinus, since on their removal, the opacity disappears. However, a thickened mucosa shadow, persists, an unequivocal evidence of its pathologic changes, a finding that agrees with the data obtained by other authors, and who find that the removal of portions of the mucosa show marked hyperplastic changes.

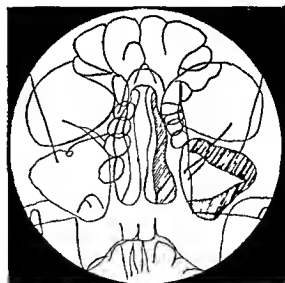
Hall and Thomas do not believe that hæmorrhage may be due to rupture of some of the newly formed capillaries in that process of the mucosa. We agree with them, for we have obtained, objectively, the impression that blood comes from a great vessel.

The fact that in almost all the instances it is possible to discover hyperplasia and thickening of the mucosa, makes these authors say that this hæmorrhage may constitute an occasional complication of hyperplastic sinusitis. We support this idea, taking into consideration the results of our roentgenogram, and also because for a long time, we have accepted as of sinusal origin the presence of blood in the nasal secretions, most



Radiograph No. 1  
 The blood fills the sinus cavity

*(All the roentgenograms are due to the kindness and skill of Dr. Aldo Berti)*



Radiograph No. 2

Immediately after the antral washing The sinus is clear showing a thickened membrane

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When the existing lesions make it necessary, one may even go so far as to remove the mucosa completely.

With regard to those measures of a general character, they are but the routine ones of any case of hæmorrhage. Coagulants of local and of general action; restoration of blood volume, when great loss has occurred (serum given intravenously; transfusion); sedatives of general action, etc.

## Summary

One case is reported, endeavouring to illustrate the possibility of some peculiar kinds of hæmorrhages having their origin in the paranasal sinuses, and contributing in this way to their better manipulation and treatment.

We present the case of a patient in whom profuse hæmorrhage had a sudden origin as well as an abrupt termination; no evidence of the nasal bleeding vessel was possible. Puncture of the maxillary sinus on the bleeding side, permitted some dark coloured clots to come out, whilst lavage and elimination of all coagulated blood within the sinus, relieved him of his subjective discomfort, and arrested hæmorrhage.

From this, we gathered that washing constitutes a simple and effective therapeutic measure that would advantageously replace surgical exploration of the sinus, making this last procedure unnecessary.

There also occurred a very interesting feature, the presence of a bluish content within the tympanic cavity, which we term "acute blue ear drum", contrasting with the chronic development blue tympanic membrane, described already by other authors. In our case, its occurrence was possibly due to blood entering the tympanic cavity *viâ* Eustachian tube, and coming out afterwards by the same route.

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## Epistaxis of Sinusal Origin

of all in the course of subacute processes with abundant secretion. When a patient tells us that he has a cold of long standing, and that the secretions in his handkerchief stain it with blood which assumes a striated shape, we question him carefully, to estimate whether he has a true acute or subacute sinusitis, and even in the absence of data confirming our presumption, we deal with our patient as though he really had a sinusal affection.

There still remains a point to be elucidated. Would it not be possible for the blood, instead of originating in the sinus, to penetrate into it through the ostium, due to packing, being thus truly of intranasal origin?—The answer to this question becomes doubtful and obscure due to lack of reasons of real value. Against this penetration is the static strength of the air within the sinus, which must be displaced in a proportional volume to that of the blood penetrating it. Furthermore, in all the cases described, there is an hyperplastic process of the mucosa narrowing the ostium and diminishing its calibre and making it less permeable. Notwithstanding these as well as other reasons that could be quoted, we think that penetration is possible, as happened in our own instance, in which blood passed down to the ear through the Eustachian tube, to give the peculiar appearance of the ear drum we wish to term *ACUTE BLUE EAR DRUM*<sup>6</sup> due to the particular circumstances of its appearance and disappearance.

With regard to *treatment* the majority of authors have operated on these cases, opening the maxillary sinus to arrest hæmorrhage. Hall and Thomas have operated on their first ten patients, but in the remaining two cases, they contented themselves with wash outs. Results were excellent, so that they regretted operating on the first cases, which might possibly have done well by simple puncture and washing. We have followed this form of treatment in our case, with such excellent result that as we have just said, not even the failed antroscopy provoked the repetition of hæmorrhage.

Besides these measures, it is very useful in these cases to apply an ice bag that soothes pain and contributes in preventing the repetition of hæmorrhage.

After washing, the cavity of the sinus may be filled with a local action coagulant.

Anterior nasal packing and in case of failure of this an antero posterior tamponing, may be useful. We do not use any kind of packing except in those cases in which other measures and attempts fail to arrest bleeding. Tamponing causes trauma, is painful, the patient does not bear it well, and in many cases its removal, unless done with extreme care unseals the blood vessel and allows the bleeding to occur again.

When all these measures have failed, it remains for us to open the sinus in order to determine with accuracy the point that bleeds and to treat it



## Eugenio Romero Diaz

When the existing lesions make it necessary, one may even go so far as to remove the mucosa completely.

With regard to those measures of a general character, they are but the routine ones of any case of hæmorrhage. Coagulants of local and of general action; restoration of blood volume, when great loss has occurred (serum given intravenously; transfusion); sedatives of general action, etc.

### Summary

One case is reported, endeavouring to illustrate the possibility of some peculiar kinds of hæmorrhages having their origin in the paranasal sinuses, and contributing in this way to their better manipulation and treatment.

We present the case of a patient in whom profuse hæmorrhage had a sudden origin as well as an abrupt termination; no evidence of the nasal bleeding vessel was possible. Puncture of the maxillary sinus on the bleeding side, permitted some dark coloured clots to come out, whilst lavage and elimination of all coagulated blood within the sinus, relieved him of his subjective discomfort, and arrested hæmorrhage.

From this, we gathered that washing constitutes a simple and effective therapeutic measure that would advantageously replace surgical exploration of the sinus, making this last procedure unnecessary.

There also occurred a very interesting feature, the presence of a bluish content within the tympanic cavity, which we term "acute blue ear drum", contrasting with the chronic development blue tympanic membrane, described already by other authors. In our case, its occurrence was possibly due to blood entering the tympanic cavity *viâ* Eustachian tube, and coming out afterwards by the same route.

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## CLINICAL RECORD

### CAVERNOUS SINUS THROMBOPHLEBITIS—A REPORT ON SIX CONSECUTIVE RECOVERIES

By J L REID and F MCGUCKIN (Newcastle on Tyne)\*

IN presenting records of six consecutive recoveries from cavernous sinus thrombophlebitis, our purpose is to illustrate the revolution in prognosis effected by modern methods, to review certain aspects of the condition, particularly the diagnosis and to discuss therapy. That the cavernous syndrome is but one manifestation of cranial thrombophlebitic pathology is fully realized, but it can conveniently be compassed within the limits of a single paper, and it does represent an entity of previously grave prognosis. Therefore all thrombotic cases not involving the cavernous sinus, though managed on similar therapeutic lines, have been excluded.

#### Cases

The case material consisted of six patients admitted between *December 1943* and *December 1945*

#### CASE I

*Bilateral Cavernous Sinus Thrombophlebitis* Female age 3

Admitted to Ear, Nose and Throat Department on 16 12 43. At the risk of confessing an error, it must be admitted that the child was seen by one of us and transferred to Professor Spence's ward as a case of suspected nephritic oedema following suppurative otitis media.

17 12 43 Seen by one of us in consultation with Professor Spence and Dr Brenda Morrison. 'Diagnosis of cavernous sinus thrombosis following acute ear with lateral sinus thrombosis, reaching cavernous *via* superior petrosal. Much too ill for any surgery.' Child moribund. Temperature 101° Pulse 124. Rigid neck. Bilateral ophthalmoplegia with gross proptosis of right side. Sulphathiazole and intravenous drip therapy had already been instituted.

20 12 43 The physicians advised us that if there were to be any surgery it must be now or never. A right simple mastoidectomy was performed and suppurating thrombophlebitis in lateral and superior petrosal sinuses located and drained. It is important to note that the child had been preserved thus far and indeed improved enough to make surgery at least a proposition, by the most careful medical and nursing care.

The next two months showed a slow recovery, very stormy at first. Complications were numerous.—VI nerve paralysis, pneumonia, whooping

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## J. L. Reid and F. McGuckin

cough ; primary pulmonary tuberculous complex. Further surgical treatment included negative exploration for orbital abscess ; right eyelids sutured twice to protect cornea ; tonsils and adenoids removed some months later.

### *Therapy*

Intravenous plasma 500 c.c. plus 400 c.c. and saline 500 c.c. ; blood transfusion 500 c.c. Sulphathiazole total 48 grams in the first 11 days giving a blood level of 6-8 mgs. per 100 c.c. during the period of grave illness. Penicillin was not available.

*Vide Photographs.*

### CASE II.

*Right Cavernous Sinus Thrombophlebitis.* Male age 16.

Admitted 27.1.44. Stye on right eyelid 8 days ago which had almost cleared up. Swelling of both eyelids 2 days ago. Severe frontal headache and vomiting. Drowsy on admission. Speech slow but coherent. Temperature 97.2°. Pulse 64. Right eye protosed and eyelids severely swollen with chemotic conjunctiva protruding. 4 grams of sulphadiazine given at once, followed by two grams of sulphathiazole 4 hourly, later given intravenously.

28.1.44. Severe headache. Frequent vomiting. Stiff neck. Kernig+. Deteriorating. Comatose at times.

29.1.44. Improvement in condition. Thereafter notes are scanty, but by 3.2.44 he was clearly doing well. At this stage eye movements were still markedly restricted but the ophthalmologists regarded this as mechanical, not paretic.

22.2.44. Discharged—very well.

### *Therapy*

Sulphadiazine and thiazole, by mouth and intravenously, totalling 48 grams within first 68 hours. After 8 days he had received altogether 101 grams and the blood-level had varied between 4.4 and 11.6, but was chiefly maintained at 8-10 mgs. per 100 c.c. Intravenous salines and glucose-saline were employed but no plasma or blood. Penicillin was not available.

### CASE III.

*Bilateral Cavernous Sinus Thrombophlebitis.* Male age 21.

Admitted 1.5.45. 8 days ago noticed a spot inside left nasal vestibule. Nose quickly became swollen. 2 days ago left eye began to swell, soon followed by right swelling. Put on chemotherapy by practitioner.

### *On Admission*

Gravely ill. Temperature 99.6°. Pulse 100. Marked dusky cyanotic swelling of nose and eyes, extending to forehead. Proptosis of both eyes and slight chemosis. Intramuscular penicillin and intravenous saline set up at once and sulphadiazine begun in 2-gram doses. Soon after admission semi-comatose. A welchii complication was suspected on clinical grounds but not confirmed until later.

3.5.45. Local cyanosis less, but swelling extended to mouth and both mastoid regions, particularly right. Both eyes grossly proptosed and chemosed. Anti-gas gangrene serum given twice daily. Seen by Mr. J. S. Arkle whose

## Clinical Record

report ends ' I should consider this a case of cavernous sinus thrombosis. Some blebs had formed on the nose end. A specimen of the fluid in these blebs was reported on by Dr Slade as follows —" aerobic culture—staph aureus, anaerobic—Gram +, gas forming, sporulating bacillus, B welchii type

4 5 45 Clear improvement in all respects Intravenous therapy discontinued

25 5 45 Developed complete right VIth nerve paralysis

4 6 45 Left hospital Very well The right abducent paralysis recovered in 2-3 months

### *Therapy*

Intravenous salines 72 hours Penicillin by intramuscular drip 700,000 units in 7 days Anti gas gangrene serum 240,000 units in 4 days Sulphadiazine 57 grams in 7 days, the highest blood level recorded being 8.4 mg per 100 c.c.

### *Note*

The delayed onset of abducent paralysis is interesting. The presence of gas forming organisms was confirmed.

*Vide Photographs*

## CASE IV

*Right Cavernous Sinus Thrombophlebitis* Female age 54

Admitted 6 10 45

### *History*

Septic spot below right eyebrow began 72 hours ago. Rapid swelling developed. Semi coma with Temperature 104° sixty hours after onset.

### *On Admission*

Temperature 103.2° Pulse 120 Extremely ill. Answers questions on rousing but seems hardly conscious of having done so. Right eye closed by firm purple coloured swelling of upper lid. Gross proptosis and chemosis. Sulphathiazole 12 grams before admission. Sulphadiazine and penicillin begun.

7 10 45 Swelling of eyelid slightly less, otherwise local condition no better—chemosis in fact worse. Patient really aware of surroundings for first time in 4 days. In the late evening she again became irrational. Urine output poor. Occasional incontinence.

8 10 45 Urine output poor. Sulphadiazine blood level 19.5 mg per 100 c.c. and drug discontinued for 24 hours when level was 6.8 mg. More rational. Chemosis still severe.

9 10 45 Improvement now clear and consistent. Discharged 24 10 45

### *Therapy*

*Sulphonamides* interrupted after 27 grams in approximately 100 hours because of failing urine output and excessive blood sulphadiazine level of 19.5 mgs. After 24 hours sulphadiazine was continued and a further 46 grams given in 9 days making a total of 73 grams in about 14 days. The second course of the drug maintained a blood level of 8.9 mgms per 100 c.c. Penicillin 100,000 units per day by 3 hourly intramuscular injection in first 48 hours. Thereafter 150,000 units per 24 hours for 8 days. Total 1,400,000 units in 10

## TEMPERATURE CHARTS





CASE I  
10 days after admission



CASE I  
1 weeks after admission



CASE I.  
7 weeks after admission.



CASE I  
15 weeks after admission



CASE III  
9 days after admission.



CASE VI  
4 days after admission





# Clinical Record

days This patient could be roused throughout and intravenous therapy was not required

## Comment

This case illustrates the need for routine precautions in all sulphonamide therapy even when the dosage is not out of the ordinary

## Vide Temperature Chart

## CASE V

*Bilateral Cavernous Sinus Thrombophlebitis* Female age 33

Admitted 24 11 45

## History

Developed small boil on right tragus 5 days ago Felt ill two days ago Two rigors yesterday Red swelling of right eyelids began 24 hours ago

## On Admission

Temperature 102.6° Pulse 124 Very ill but fairly rational if roused Right eye—severe swelling both eyelids, gross proptosis and chemosis, eye fixed Left eye—moderate oedema, restricted movements Small infected lesion right tragus Put on 3-hourly intramuscular penicillin in dosage of 12,500 units Sulphadiazine by mouth

25 11 45 Irrational Forehead oedematous and cyanotic Both eyes fixed Rigid neck Penicillin dosage increased to 25,000 units 3 hourly Glucose-saline-sulphathiazole drip put up

26 11 45 Irrational Eyes closed, herniating chemosis Forehead plum-coloured, Turbid CSF with 118 leucocytes per cmm 50,000 units penicillin intrathecally

28 11 45 Drowsy and irrational but slightly improved

30 11 45 Clear mentally Livid discolouration rather less

10 12 45 Both eyes well open Merely red conjunctivae Doing well

28 12 45 Home Very well

## Therapy

Systemic penicillin 3,000,000 units in 21 days Intrathecal penicillin 150,000 units given in 3 doses of 50,000 units in 2 c.c. on 3rd, 5th and 6th days after admission Anti-gas gangrene serum 16,000 units day after admission Sulphathiazole and sulphadiazine by mouth and intravenously, 55 grams in 7 days Intravenous saline and glucose saline on 3rd, 4th and 5th days after admission

## Vide Temperature Chart

## CASE VI

*Right (and possibly Left) Cavernous Sinus Thrombophlebitis* Female age 20

Admitted 30 11 45

## History

"Small spot" over right temporal fossa 9 days ago Next day right eyelids swollen and blue Left eye involved 2 days later Her doctor gave her 12 grams of some sulphonamide which the girl took within 24 hours No further therapy during past 4 days

## On Admission

Temperature 100° F Pulse 88 The condition was the most arresting we

have ever seen. The whole face from the lower eyelids upwards was grossly swollen and purple in colour, and both eyes proptosed; and yet through this dusky colour every vein over the whole area was strikingly outlined by almost black thrombosis, the appearance being rather like blue-black roads outlined on a purple map. Blind, unless the eyelids were forced open, when severely chemotic conjunctiva escaped, sight was in fact normal in each eye. In spite of this the patient's cerebration was normal, she had neither ache nor pain, and took food and drink with satisfaction when administered. The remains of a small spot or superficial abrasion were found in the skin of the right temporal fossa. Systemic penicillin 200,000 units per 24 hours and sulphadiazine therapy started, the latter in 4, 2, 1 gram doses to begin with.

1.11.45. We were able to watch the gradual *retrograde* thrombosis of the right angular vein on this day.

2.11.45. Œdema slightly less. For some reason not recorded in notes sulphonamide was stopped pending a blood level. Next day this was only 2.2 mgms. but the drug was not restarted.

3.12.45. Two pustular areas formed in thrombosed veins near hair-line. Quite a number of these developed later beyond the hair-line and, over the whole area involved, the patient went bald for some weeks. Cultures from these thrombophlebitic suppurations yielded staph.p.aureus.

4.12.45 and subsequently—clear improvement. There was never any real anxiety with this case (which had indeed earlier been an ambulant case of extensive thrombosis) although the temperature remained unsteady for three weeks.

10.1.46. Home.

## *Therapy*

Sulphadiazine 18 grams in first 52 hours. Systemic penicillin 3,400,000 units in 22 days, beginning with 200,000 per 24 hours, later reduced to 100,000. No intravenous therapy.

## *Vide Photographs*

*N.B.*—Photographs were obtained not when desired but when it was possible as the dates will show.

## Canons of Diagnosis

Twenty years ago Eagleton (1926) laid down six criteria as necessary to the diagnosis. These were reviewed 15 years later by LeRoy A. Schall (1941) and we think it useful again to consider the points seriatim with comment on each based on our experience of the present series and numerous cases in the past.

### 1. *Known Site of Infection.*

In the present series the known sites were: otitic lateral sinus thrombosis—1 case; styes—2 cases; furuncles—1 tragal and 1 nasal; "A small septic spot"—1 case. These lesions include most of the common causal factors. The present series showed no instance of peritonsillar origin, but past experience has yielded 4 such cases. In almost 20 years there has been no case in the department of sphenoidal origin. *We would stress that the known site of infection may be nothing more than a trivial abrasion of skin.* Thereafter it needs only the

# Clinical Record

right type of coccus with a predilection for the formation of septic thrombo phlebitis, to start the pathological process

## 2 *Blood Stream Infection*

None of our cases was controlled by blood culture, but some patients showed ample clinical evidence of septicæmia. A positive culture may be very satisfying academically, when it would indicate failure in maintenance of protective clotting, but our opinion is that a negative result would not negative the diagnosis

## 3 *Early Signs of Venous Obstruction*

This may be considered a *sine qua non* and most patients show much more than this, *e g* "mapping out" of thrombosed veins in case VI. However, even before there is evidence of significant œdema there may occasionally be visible the spread of clotting along a vein, in which event active measures should begin at once. We regard not only proptosis, but also chemosis as necessary to the diagnosis

## 4 *Involvement of Nerves in the Sinus*

This point is open to criticism because in so many cases fixity of the eye can be explained by mere œdema and displacement, though we have seen examples of true paresis, *e g* Case IV in which paresis was delayed. A reacting pupil is no bar to the diagnosis

## 5 *Neighbourhood Abscess of Soft Parts*

If this ever was a necessary canon, it no longer holds good. Modern therapy should aim at prevention of abscess formation both inside and outside thrombosed veins, in the past many cases died without a visible "neighbourhood abscess"

## 6 *Symptoms of Complicating Disease*

Complications, for example meningeal and metastatic, still occur but are unnecessary to the diagnosis, as these are frequently preventable with the means now at our disposal

In presenting the case material as the evidence for judgment of the accuracy or otherwise of our own canons, we suggest a different and much less rigid approach to the diagnosis. Armed with the pathological principle that cavernous sinus involvement is merely an extension of a disease process already begun in less vulnerable sites, the experienced clinician will judge his case on the gravity of the patient's condition, actual or impending—on the increasing orbital œdema, the appearance of proptosis, and especially of chemosis, on the increasing fixity of the eye whether this be mechanical or parietic. Other features may add detail to a picture already sufficiently plain—visible or palpable thrombosed veins, local cyanosis, meningitis, septicæmia, metastatic spread, and so on. And in case of reasonable doubt an appeal to one's colleagues especially the ophthalmologists, will enforce objective criticism. In parenthesis it may be pertinent to note that our successors may become more and more dependent on past necropsy records in order to picture the living pathology of these lesions

# J. L. Reid and F. McGuckin

## Therapy

Improved nursing standards, care for fluid balance, and other "supportive" measures have doubtless contributed, but we hold that sulphonamides and penicillin are chiefly responsible for the change in prognosis.

Cases I and II recovered on sulphonamides, penicillin not being available, but experience suggests that convalescence would have been easier and shorter in Case I if both drugs had been used. Case VI might have recovered without penicillin, possibly even Case IV, but we think that Cases III and V would have proved fatal in its absence. In cavernous sinus sepsis, as in septic meningitis the best and quickest results are likely to attend the use of both drugs.

Should therapy await sensitivity-tests? We believe not, because the organism may not be available, no time should be lost, sensitivity is relative rather than absolute, and chiefly because on clinical grounds it can be stated that the great bulk of cavernous sepsis arises from sensitive organisms. However, we do not deny the interest or the value of such tests where organisms and facilities are available.

Our provisional opinions on therapeutic detail at this date are as follows:

## Sulphonamides

We now prefer sulphamezathine to sulphathiazole, except in meningitis when sulphadiazine is the drug of choice, because mezathine has produced less renal and "toxic" troubles. The aim has been to maintain a level of 8-10 mgms. per 100 c.c. of blood during grave illness, and this has so far proved adequate, though apparently much less than current American practice.

The usual precautions have been employed roughly in this order—check on intake and output of fluid, pot.cit. and soda bicarb. administration, drug blood-levels, white-cell counts, urine microscopy, blood-urea. We demand the initialling of every dose of drug given. In unconscious patients sulphonamide was given *via* the drip, otherwise by mouth.

## Penicillin

Our present systemic recommendation is to give 15,000 units in 1 c.c. of pyrogen-free solution by intramuscular injection every 3 hours, increased to 25,000 in grave cases where it is felt that greater tissue fluid concentration may possibly help. The intramuscular drip method was abandoned as unsatisfactory, at least in our hands.

It is to be noted that *meningitis developed in Case V during receipt of full systemic penicillin and the complication was controlled by 3 doses of 50,000 units (in 2 c.c. of pyrogen-free solution) given intrathecally*. Similar dosage has been employed quite frequently in other meningeal cases, so far without trouble. Recent opinion, however, seems to be hardening against such quantities and we may need to review the matter, if only on the score of waste.

## Heparin

In Case I, we debated with Dr. Brenda Morrison the merits of this antithrombotic drug and all agreed that it be rejected. Rightly or wrongly, we placed the accent on the phlebitis rather than on the thrombosis and considered clotting a protective mechanism, probably ceasing when the call no longer existed. It may be that clot forms a barrier behind which bacteria grow and that its dissipation allows of the better action of a blood-borne drug; but we agree with the *Lancet* Annotation of 16.3.46 (p. 391) that "there is no

# Clinical Record

convincing evidence that better results are being obtained with penicillin plus heparin, than with penicillin alone, and there are added dangers with heparin " even though this particular remark was applied to bacterial endocarditis and not to cavernous thrombophlebitis

## *Intravenous Therapy*

In Case I, salines, plasma and blood were given entirely at the discretion of Dr Brenda Morrison. In the remaining patients intravenous N-salines and glucose 1/5 N-salines were used whenever coma or lack of co operation threatened the fluid balance, but not otherwise. Under these conditions sulphonamides were given *via* the drip.

## *Anti Gas Gangrene Serum*

In these and similar cases we have used this serum when gas-infection was suspected, as we think it should be where facial swelling and livid discoloration are extreme. Two of the present series received it, and in one the infection was proved.

## *Nursing*

We cannot stress too strongly the need for devoted nursing care, for without the co-operation of the ward staff adequate therapy is impossible.

## Summary

Six consecutive cases recovering from cavernous sinus thrombophlebitis are presented to illustrate the change in prognosis.

The canons of diagnosis laid down by Eagleton 20 years ago are reviewed in the light of current experience.

The therapy employed had been presented in detail and discussed in general.

## Conclusions

Without suggesting that cavernous sinus thrombophlebitis has ceased to be a grave lesion, it is clear that the prognosis has radically altered.

Intensive modern therapy, preferably combining sulphonamides and penicillin, is justified even when the case by previous standards appears hopeless.

We record our appreciation of Professor Spence's wise guidance, and of Dr Brenda Morrison's admirable medical care of Case I, which was nursed in the Child Health Department, and of the assistance of our biochemical, ophthalmic, bacteriological and Ear, Nose and Throat colleagues, Dr Freda Herbert, Mr J S Arkle, Dr J H Slade, and Mr R G Hughes.

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## CLINICAL NOTES

### VASOMOTOR RHINITIS—TREATMENT BY SUBMUCOUS INJECTION OF PHENOL

By MORTON MARKS (London)

THE terms vasomotor rhinitis and allergic rhinitis are regarded by most authorities as synonymous. In practice however, two distinct clinical pictures present themselves in this type of case. There is the patient whose main symptoms are those of alternating nasal obstruction and attacks of sneezing, usually without any seasonal variation. On examination his nose presents a reddened congested appearance with the inferior turbinates swollen and elastic. These cases are unassociated with eosinophilia and are in the category which should be classified as vasomotor rhinitis.

Patients coming into the group classified as allergic rhinitis very often give a seasonal variation or periodicity to their symptoms. These are mainly rhinorrhœa, sneezing and nasal obstruction. The nose in these cases presents a pale, stippled and sodden appearance, often associated with polyposis and true hypertrophic areas. Eosinophilia is always present in these cases. The ætiological factors in both types are similar, but for the fact that in the vasomotor cases it is rare to find any underlying allergic factor, and therefore attempts at desensitization are largely unsuccessful. In the allergic types an underlying allergen is more frequently discovered and thus in a certain number of cases desensitization is of great value.

#### Choice of Cases

It is important to make a distinction between the two types of cases, for as will be shown, the results of treatment vary in each type. The cases selected for injection treatment were of both types, in which all other forms of treatment had been carefully carried out but were unsuccessful. Such previous treatment consisted of :—

- (i) Skin testing the patient and if found sensitive to any specific substance, a subsequent course of desensitization was undertaken.
- (ii) A nasal spray of 1 per cent. Ephedrine in normal saline t.d.s.  
Ephedrine  $\frac{1}{2}$  grain t.d.s. by mouth.  
Calcium gluconate 30 grains t.d.s. by mouth.
- (iii) Linear cauterization of both inferior turbinates and local cauterization of any hypersensitive spots in the nose with the galvano-cautery.
- (iv) A course of zinc ionization to the nose.

This treatment was carried out in progressive stages in the order shown above, recourse to the next stage being undertaken only after adequate trial and subsequent failure of the previous stage. Thus it is seen that only very resistant cases were chosen for treatment.

# Clinical Notes

## Method of Treatment

The solution used is a 5 per cent. solution of Phenol in Arachis oil. A 5 c.c. syringe preferably of the Labat pattern, with a long wide bore needle, is employed. The anterior end of the inferior turbinate at the proposed point of entry of the needle is painted with cocaine, just sufficient to render the injection painless without causing contraction of the swollen turbinate. The needle is thrust deeply into the cavernous tissue of the inferior turbinate as far as the posterior end. Whilst slowly withdrawing the needle, 2 c.c. of the solution are injected. The injection is quite painless and no after-effects are experienced. It is repeated on the other side. Some slight hæmorrhage may occur as the oily mixture temporarily prevents clotting. After an adequate injection the inferior turbinate should appear blown up and completely fill the lower part of the naris throughout its whole length. The injection may have to be repeated again a week later.

The rationale of the treatment is really palliative to the main symptom of nasal obstruction and rhinorrhœa. By depth injection the vascular bed of the inferior turbinates are largely sclerosed, with consequent diminution in fluid transudation and great reduction in size. The main advantage of the method over the surface galvano-cautery being that the mucous membrane is not destroyed and is given the chance of resuming its normal function. A week after the injection, the turbinate appears shrunken and of normal consistency without any scarring or destruction of the overlying mucosa.

## Report of Cases

### CASE 1.

Male aged 38. Occupation—General Fitter.

First attended complaining of nasal obstruction and anosmia for 10 years. Examination showed him to come into the classification of vasomotor rhinitis. Complete course of treatment referred to above produced no improvement. After 2 injections at one week's interval of 2 c.c. of phenol into each turbinate the sense of smell had returned and the nasal congestion had entirely disappeared with restoration of a good airway.

### CASE 19.

Female aged 32. Occupation—Tailoress.

First attended in *October, 1944* complaining of nasal obstruction and headaches for seven years. Classified as a vasomotor rhinitis and treated with the usual regime to no avail. 2 c.c. of phenol injected into each inferior turbinate. After one injection the general congestion had completely subsided with production of an excellent airway. The patient stated that she felt a new woman.

### CASE 27.

Male aged 26. Occupation—Machinist.

Attended complaining of headaches, nasal obstruction and rhinorrhœa. Discharged from the army on account of his symptoms. Examination showed the nose to be of the allergic type. Desensitization and other treatment was of no benefit. After two injections of phenol the sneezing and headaches had ceased, while the airway was considerably increased.



# Morton Marks

## Results of Treatment

<i>Types</i>	<i>Symptomless</i>	<i>Improved</i>	<i>No Improvement</i>
Vasomotor Rhinitis	23 (92%)	2 (8%)	—
Allergic Rhinitis	17 (68%)	5 (20%)	3 (12%)

From a study of 25 cases of each type, it has been found that the results in the vasomotor cases were invariably excellent. In the allergic type 17 cases were rendered symptomless, 5 considerably improved, with only occasional return of symptoms and 3 were not helped at all. Each of these cases have been observed for a period of over 12 months after cessation of treatment.

Subsequently over 100 further cases have been treated, but these have not been observed over such a lengthy period. Preliminary results, however, appear to confirm those recorded above.

No claim for originality is made for the above method of treatment as a somewhat similar regime has been used in America and on the Continent. However it is rarely used in this country, and in view of the good results obtained in cases, in which all other methods of treatment have failed, I feel that it warrants a wider consideration and a greater usage.

## Summary

A report of 50 cases of allergic and vasomotor rhinitis treated by injection of phenol solution into the inferior turbinates is submitted. These cases were all resistant to other forms of treatment. Results were good, and demonstrate the value of this method particularly in difficult cases.

## CASE OF PERFORATING WOUND OF THE TRACHEA

By K B BELLWOOD (Bedford).

In *May, 1945*, a boy of 14 came to Hospital complaining of Dyspnoea, and bringing a bent and torn percussion cap originally belonging to a cannon-shell case

Half an hour previously he had been trying to prize out the cap from the shell case, which he had fixed in a vice. While hitting it with a chisel and hammer, the cap exploded and shot straight into his neck, inflicting a small round bruised wound in the mid line immediately above the suprasternal notch. He choked and gave a violent cough, and spat up the percussion cap!

On examining this, it appeared to be complete, if much distorted. The boy was slightly blue, with a definite dyspnoea and there was surgical emphysema over the front of the neck.

On being X-rayed, no foreign body was found in the neck or chest, but he had a well marked pneumothorax on the left side. We were at a loss to explain this, unless the violent cough had ruptured some old lung lesion.

As his condition was rapidly becoming worse and the emphysema had reached the costal margin, a Tracheotomy was done. There was a small sucking wound of the trachea, almost exactly mid-line, involving the 2nd ring, and by extending this downwards a tube was easily introduced.

The boy made rapid recovery, the tracheotomy tube being removed in 48 hours, and the emphysema cleared in about a week, the pneumothorax had cleared when he was examined four weeks later.

The low level of the wound would be explained by the involuntary extension of the head at the time of the explosion. The most remarkable point in the case is the coughing up of the cap, it must have hung momentarily in the tracheal wall, to be dislodged and expelled by the cough.

# SOCIETIES' PROCEEDINGS

## ROYAL SOCIETY OF MEDICINE—SECTION OF LARYNGOLOGY

March 1st, 1946

*President*—G. EWART MARTIN, F.R.C.S.Ed.

### Discussion on Idiopathic Recurrent Laryngeal Nerve Palsies

MAXWELL ELLIS: The terms of reference restrict this discussion to about one-quarter to one-third of all cases of recurrent laryngeal nerve paralysis—a figure common to a number of statistical surveys of which the more recent are by New and Childrey (1932), Smith, Lambert and Wallace (1933), Work (1941) and Suehs (1943). The cases represented are drawn from widely different areas in America and Britain, and this agreement in incidence of a disease of unknown ætiology is remarkable and may indicate the constant presence and effect of some unknown, or unsuspected, disease process. The absence of any gross or demonstrable lesion has stimulated speculation. The most popular conception ascribes the condition to an insidious invasive peripheral neuritis secondary to some circulating toxin, or to a vitamin deficiency, or to rapid change in temperature. I fancy that glandular dyscrasia and allergy could be added without fear of contradiction. However, it is fair to mention that Alcantaro and de Ocampo (1939) investigated the larynges of 37 infants suffering from beri-beri and found in 31 cases a partial or complete paralysis of a vocal cord. They believe that irritation of the recurrent laryngeal nerve occurred, followed by degeneration, and dismissed the possibility that pressure on the nerve due to the associated cardiac enlargement might have been responsible. These laryngeal findings are extraordinary, and have been seen recently in returned prisoners of war suffering from nutritional disorders. A few cases occurring during acute infections and after direct exposure of the neck to cold are recorded, but in the bulk of cases no such history is obtainable.

Males are affected nearly twice as frequently as females, and the left cord nearly twice as often as the right. Both cords are involved in only 10% of cases, or even less. The first and second of these observations could lend some support to peripheral neuritis as a cause, since males are more likely to undergo exposure to both weather and infection, and the left recurrent nerve from its greater length is more vulnerable to adjacent disease. But, when all is said, the mere presence in this group of any case proclaims failure in discovering a precursory incident of ætiological significance.

### SYMPTOMS

Hoarseness or a weak voice are the usual symptoms for which the patient seeks advice, and choking or coughing attacks may occur on deglutition.

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Routine post-thyroidectomy laryngoscopic examination has shown that one-third of all cases of unilateral paralysis following the operation are symptomless. It therefore is likely that a number of idiopathic unilateral cases never come for examination and consequently are not recorded. Bilateral paralysis is usually accompanied by dyspnoea on exertion, or even at rest, and sometimes by stridor. This gradation in symptoms of impaired respiratory movements is a function both of the general build and occupation of the patient, and of the relative position of the vocal cords. The former needs no special description, and the latter has probably received overmuch since the paper published by Semon in 1881. The size of the glottic chink is the all-important and vital factor in prognosis.

## PROGNOSIS AND TREATMENT

Unilateral paralysis occasionally recovers spontaneously, but in any case the disability is slight, the prognosis therefore good, and treatment unnecessary. Bilateral paralysis seldom undergoes a natural resolution, and it is the chief concern of the practical laryngologist, as fatal asphyxia may at any moment supervene. Prognosis, at the best, is uncertain, and, at the worst, disastrous. These cases are rarely of rapid onset, but they then present no problem as immediate tracheotomy is imperative. When the onset is slower, hasty action is unnecessary, but early decision is desirable if the patient is to return to anything like a normal existence. For many years these cases have been treated by permanent tracheotomy, but such a permanent fistula has certain obvious disadvantages, although when properly constructed low down in the neck and properly managed it need cause only minimal discomfort. However, the patient almost invariably will exert the maximum pressure to rid himself of this disfigurement. Earlier surgical approaches to the problem were first to restore function by nerve anastomosis, and secondly to restore airway by excision of some of the apposed soft tissues. Nerve anastomosis, usually joining the recurrent laryngeal to the descendens hypoglossi, has not proved entirely satisfactory, as in late cases fixation of the crico-arytenoid joint and atrophied muscles are present. Excision of portions of the true and false vocal cords was nearly always followed by the growth of obstructive scar tissue. Following this same principle, Hoover (1932) performed a submucous resection of the vocal cords and soft tissues of the larynx, hoping to secure adhesion of the mucosa to the internal surface of the thyroid cartilage by firm packing. This procedure has not been altogether successful. Kelly (1941) has introduced a new principle by excising the arytenoid cartilage through a transthyroid approach, hoping (a) that the tension of the vocal cord would disappear, allowing it to fall away from the mid line, (b) that the respiratory space left posteriorly by removal of the cartilage and atrophy of the cut muscles would be obliterated by scar tissue and remain permanent, and (c) that the position of the anterior third of the cord would be relatively unaltered, preserving a serviceable voice. He has performed this operation on a number of cases and finds that the result is functionally satisfactory. This orthopaedic principle was adapted from another introduced by King (1939 and 1940), who began by performing an arthroplasty of the crico-arytenoid joint combined with a tendon transplant (using the anterior belly of the omohyoid), and ended by discarding the transplant and creating an arthrodesis of the joint with the

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arytenoid fixed in abduction and external rotation. The approach is posterior after dividing most of the attachment of the inferior constrictor muscle to the posterior border of the thyroid ala. The posterior crico-arytenoid muscle is divided at its insertion into the base of the muscular process of the arytenoid, the crico-arytenoid joint is opened widely, and the arytenoid freed from the fibres of the interarytenoid muscle along its posterior border and body, and from those of the lateral crico-arytenoid along the anterior border. The vocal process is then encircled by a catgut suture which is drawn through the lamina of the thyroid cartilage and tied so that the arytenoid is fixed in abduction and external rotation. King found by experience that the best result was obtained by operating on only one side, but if there is sufficient airway the other side should be treated likewise. He also found that patients can both open and close the vocal cords, although the larger range of movement develops on the unoperated side. The cord on this side will frequently pass across the mid-line in phonation. He considers that these movements are due to the action of the cricothyroid muscles in increasing the antero-posterior diameter of the larynx, drawing the cords towards the mid-line.

Most of the experience gained in treating bilateral recurrent nerve paralysis has been on cases following injury to the nerve, generally during thyroidectomy, as bilateral idiopathic paralysis is uncommon, but there is no reason why the same principles should not apply. My only personal experience of the Kelly and King operations has been on the cadaver, but the technique is not essentially difficult although one must be prepared to be painstaking in defining anatomical landmarks clearly, and in the precise placing of the anchoring sutures.

### SUMMARY

In idiopathic recurrent laryngeal nerve palsies no cause has yet been discovered, but peripheral neuritis is a possibility. Unilateral cases are accompanied by few symptoms, are of reasonably good prognosis, and require no treatment. Bilateral cases are uncommon and always require some form of surgical treatment, of which permanent tracheotomy is the simplest. Recently operations on the arytenoid cartilage and crico-arytenoid joint have been devised, which are rational in conception, not especially formidable in technique, and reasonably successful in outcome.

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MACDONALD CRITCHLEY: Perhaps I can best contribute to the symposium by discussing the phenomenon known as Semon's law and in particular its possible explanation.

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In the German edition of Morell Mackenzie's textbook—translated and edited by Felix Semon—we find the following footnote “ in many cases in which central or peripheral lesions unquestionably affect the whole nerve (most frequently in cases of pressure upon the entire trunk of the recurrent laryngeal nerve in cases of aneurysm of the aorta) the symptoms of paralysis of glottis openers only are seen during life This proclivity of the fibres going to the abductors to be affected exclusively or long before the others, is very strange ”

It was indeed strange and quite unexpected But Semon had noted it in a series of his own patients and had reported it at the Clinical Society of London in 1878 By 1881 he had been moved to publish in the newly appearing *Archives of Laryngology*, a paper—now a classic—under the elaborate title “ Clinical remarks on the proclivity of the abductor fibres of the recurrent laryngeal nerve, to become affected sooner than the abductor fibres, or even exclusively, in cases of undoubted central or peripheral injury or disease of the roots or trunks of the pneumogastric, spinal accessory, or recurrent nerves ”

But unfortunately he had been forestalled a few months before by Rosenbach, who upon the basis of a solitary case of carcinoma of the œsophagus had stated “ in compression of the trunk of the recurrent, the function of the abductors suffers first, and that of the adductors is implicated only later on ”

The eponymous term Semon's Law has rightly passed into medical terminology, though some Continental sticklers may continue to speak of the Rosenbach-Semon law, or even the Gerhardt-Rosenbach-Semon law

With the passage of sixty years it is not surprising that cases should occasionally be reported which show themselves (or appear to) as exceptions to this law Perhaps it is a matter for wonder that the exceptions have been so few But for this reason some—like the Chevalier Jacksons—would prefer to speak of Semon's rule rather than Semon's law, a distinction which might be regarded as a quibble

Perhaps the majority of those exceptions comprise pseudobulbar laryngeal palsies, due to supranuclear lesions This at least is what Semon afterwards affirmed, namely in 1913, when he emphasized that his law only concerned the laryngeal nerves from the nucleus downward Semon must, however, bear some of the blame for this misconception, for all his early papers on the subject referred to both peripheral and central lesions By “ central ” Semon probably meant “ nuclear ” lesions, though most present-day neurologists might well assume these to refer to supranuclear locations

Anyway the point is a good one, and the fact remains, I think, that supranuclear affections of the nucleus ambiguus do not necessarily behave according to Semon's law, e g in cases of pseudobulbar and progressive spastic bulbar paralysis, as shown by Collier Critchley and Kubik, and others

Later authors have read more into the law than Semon originally stated in that it is now taught that with progressive affections of the recurrent laryngeal nerve, the abductors are the first to be affected, while the tensors of the cords are implicated later, and the adductors last of all Or, in terms of the muscles involved, the crico-arytenoideus posticus suffers first then the thyro-arytenoideus, and lastly the crico arytenoideus lateralis The

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arytenoideus, having a bilateral nerve supply, is not affected in unilateral cases, while in bilateral disease it is affected very late.

Experimental physiologists have since shown that the law holds true for processes other than pressure effects or disease. Thus the adductor components of the recurrent laryngeal nerve have proved to be more sensitive than the adductor elements to such influences as drying (Risien Russell) and to freezing (Gad and Fränkel).

The many and diverse views that have at various times been proposed to explain Semon's law may best be arranged in chronological order.

*Muscular hypotheses.*—(a) Abductor group requires a greater volume of blood (Claudberg). (b) Abductors differ in chronaxy from the adductors (Tarneaud). (c) Abductors early lose their excitability after death (Jeanselme and Lermoyez). (d) Adductors are mechanically better placed than the abductors (Gowers). (e) Abductors suffer because the nutrient artery is involved (Robinson).

*Location of abductor fibres within the recurrens.*—A more peripheral siting of the abductor fibres suggested (M. Mackenzie).

*Double innervation of adductor group.*—(a) From spinal components (Tissier). (b) From superior laryngeal nerve (Cohen Tervaert).

*Abductor parcsis is really an irritative adductor spasm or adductor contracture* (Krause).

*Glottis-closure is subserved by a powerful cortical centre* (Bosworth ; Risien Russell ; Horsley).

*Abductor proclivity is an instance of a general axiom that extensors are more vulnerable than flexors* (Ferrier).

*Glottis-closure is phylogenetically an older function of the larynx than is the opening of the glottis* (Ncguis).

Some of the foregoing suggestions can be disposed of quickly.

Morell Mackenzie's original idea was that the abductor fibres were disposed peripherally in the recurrens and were therefore sensitive to pressure. But Risien Russell later showed that the abductor filaments lie mesially and the adductor filaments laterally.

The theory of double innervation is a plausible one, but is not supported by anatomy, though bilateral innervation of the arytenoideus is of course a factor which may assist in maintaining closure of the glottis in unilateral lesions of the larynx. The fact that Semon's law applies to lesions of the vagus as well as the recurrent, and its occurrence in bilateral lesions of the larynx, are points against the theory of double (or bilateral) innervation.

Spasm of adduction (rather than weakness of abduction) is a not unnatural suggestion, and was at one time entertained by Semon himself. But subsequent experience rendered this idea unlikely, (1) because the adductive process was observed at times to continue for years—far longer than nerve-irritation was likely ; and (2) because dissection of the laryngeal muscles confirmed a greater degeneration in the abductor set. Krause's theory of primary neuropathic contracture of the adductor muscles was the basis of another prolonged controversy, and here again Semon was able to point out that when laryngeal palsies accompanied multiple palsies elsewhere in the body, loss of power, and not contracture, was the rule.

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The rôle of the cortex was regarded as a possible explanation, and, supported by most careful experimental work by Risien Russell, Horsley and Semon himself, has never been really put out of court. It ties up with the older conception of the dual rôle of the larynx, the adductive elements being connected with phonation and the abductive elements with respiration. The former was found to have considerable representation in the cerebral cortex, the latter having mainly a medullary hierarchy—though the circumstances differed slightly according to the kind and age of the animal studied.

Much attention has been paid to the idea that Semon's law is merely part of what might be called Ferrier's law, which states that in neurological disease the extensors of the limbs are always affected more than the flexors. It was imagined that the limb extensors correspond with the laryngeal abductors and the flexors with the adductors. Semon, however, pointed out that to invoke a general law of extensor vulnerability was merely to restate the problem and simply to postpone the explanation. (Indeed the correctness of Ferrier's law is open today to serious doubt.) Semon made the point that both flexor and extensors of, say, the lower limb subserve the same functions of posture and of progression while the adductors and abductors of the larynx serve two separate and distinct functions, namely phonation and respiration. Secondly, abductor palsy is characteristic of organic disease and adductor palsy of hysteria, whereas no such selectivity occurs between functional and organic paralysis of a limb. Lastly Risien Russell had found that after division of the adductor filaments of both recurrents, stimulation of the cortex would not produce any inhibition of the abductors such as would be expected to occur in the case of true antagonistic muscles.

The brilliant researches of Negus have afforded what is so far the most satisfying solution to the problem of Semon's law. Far from subserving two functions as Semon taught, the larynx according to Negus has several, of which the most primitive is that of shutting off the air passages from the gullet. For this purpose a sphincteric muscle at the entry of the larynx was developed, the homologue of the adductor group. Both phylogenetically and ontogenetically the glottis closers are the oldest structures in the larynx and presumably therefore are more resistant than structures of later appearance and development.

Today this is perhaps the most plausible way of accounting for Semon's law though one must admit that as an hypothesis it is not completely satisfying. The sphincteric conception of the larynx is perhaps an over-simplification. Most sphincters—if not all—are endowed with a sympathetic as well as parasympathetic innervation, which is not the case in the larynx. Furthermore, the interpolation of the arytenoid cartilages and the division of the larynx into upper and lower compartments detract from the idea of a simple valve like or sphincteric action.

Nevertheless it is not unfair to regard the larynx as being made up of muscular structures of different ages, functions and degrees of vulnerability. Hence we are really back again in 1913 when Semon himself could only conclude that the earliest destruction of the abductors in progressive lesions implies that there exists an actual difference in the biological composition of the laryngeal muscles.

Perhaps a study of phonetics might throw some light upon the problem.



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The appearance of the so-called "glottal stop" is an early but important landmark in the development of infant speech and is mediated by structures which exclude food from the air passages. Their ancillary influence upon phonation is to evoke the guttural sound [k] (unvoiced) and more especially the voiced guttural sound [g]. The vocalization of newly born babies is chiefly made up of vowel sounds. Consonantal sounds appear later. Although more data are required, it is possible—if not probable—that the voiced and unvoiced gutturals are among the earliest of the consonantal cries and appear within the first month. We believe that in early infancy, vocalization denotes discomfort, and silence means satisfaction. But at a little later date the infant becomes capable of emitting comfort noises. These are symbolized by consonantal sounds of later appearance. In other words the earliest consonantal sounds are mediated by the glottal stop, i.e. the adductor elements, and connote discomfort. The wide range of abductor sounds associated with comfort appear later.

Much more work is required along these lines but already it seems as though phonetics might produce a confirmatory piece of evidence and serve to bring Semon and Negus still further into line.

E. D. D. DAVIS: The term "idiopathic" means without pathology and without cause. Paralysis of the laryngeal nerve of unknown or obscure origin is what is really meant. Paralysis of the left or right recurrent laryngeal nerve is common in pulmonary tuberculosis, caused by enlargement of the mediastinal glands. The tuberculous lesion may heal and the paralysis may disappear or remain. Similarly cases of syphilis causing double abductor paralysis recover with treatment and in both diseases the original cause of the paralysis may be obscure. Paralysis of the laryngeal nerve occurs in thrombosis of the posterior inferior cerebellar artery and this paralysis sometimes remains after all the other symptoms have disappeared. Bilateral or unilateral abductor paralysis arising from enlarged mediastinal glands has occurred on very rare occasions in children. Such cases of laryngeal obstruction have been admitted to the Fever Hospital for suspected diphtheria and a tracheotomy has been necessary. Mr. Ridout showed a post-mortem specimen of such a case at this Section many years ago. Enlarged mediastinal glands had stretched the nerves.

The enlarged glands are not always easily recognized by X-ray photographs and these cases may be described as of obscure origin. I have seen 5 cases of double abductor paralysis following thyroidectomy which I have kept under observation for some years.

The first case developed double abductor paralysis a short time after the operation. This woman had a tracheotomy performed and was more or less an invalid all her life and did not attempt to go to any social function. The next case, a young woman of 22, kept her household awake at night with her noisy stridor. She was embarrassed on exertion and had attacks of dyspnoea. She married and when she was pregnant it became necessary to terminate the pregnancy owing to the difficulty in breathing. The right phrenic nerve was united to the right recurrent laryngeal nerve and when seen a few years later there was no movement of the right cord. The patient thought she was better but there was no alteration in the abductor paralysis. This patient has attacks

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of bronchitis of the base of the right lung with retention of secretion. These cases after some years show relaxation of the adductor muscles and particularly the interarytenoideus or transverse muscle. The larynx shows an elliptical chink between the anterior two-thirds of the vocal cords, and a larger triangular area between the arytenoids, making almost normal respiration possible. The question is, can the patient wait for this happy result without a catastrophe?

If tracheotomy is performed it should be a low one and a tracheotomy tube would have to be worn for many years.

Double abductor paralysis of syringobulbia is not always complete and occasionally there is slight movement of one or both cords and also the adduction of the cords is not so marked.

LIONEL COLLEDGE said that he had been interested for a long time in the question whether it was possible to restore movement to a paralysed cord. It was not of much consequence where the paralysis was unilateral, because that only very exceptionally produced any respiratory difficulty. Attempts were made by Ballance and himself in 1925 to discover whether by any form of nerve anastomosis movement could be restored to one or other side. Most of the nerves of the neck were tried, including the descendens noni which had been mentioned. No good result was obtained with the descendens, but satisfactory results were claimed in America. When the recurrent was divided either the cord might remain in its previous position, median or paramedian or it might be moved out, depending on the length of time of the paralysis and the degree of contracture of the muscles. If the contracture was firmly fixed at any one position the cord would not move out. That was all that happened with the descendens.

They tried on monkeys the effect of using the phrenic, which seemed more promising, because respiratory impulses were going down the phrenic, and therefore there was more hope of restoring respiratory movement to the cord. Experimentally it worked very well in animals. In one case it was possible to show a monkey with both cords moving quite freely on the phrenics. Therefore he tried operation on the human being on this experimental basis. He had carried it out on 5 patients. In 2 nothing happened at all. One was a woman with a bilateral recurrent paralysis following thyroid operation, and there was no result. In another there was the same thing, and in both these cases a tracheotomy was done. The third case was a man with what Mr. Davis would call paralysis of unknown origin. The cord moved out (in the other 2 it did not move at all), but he got an infection of the arm about six weeks later to which he succumbed.

The other 2 cases were both in young women. One, he felt sure, succeeded quite well because the patient was able to dance and lead quite an active life after being in a state of very restricted activity, but he had not seen her for a long time. The other one was the case to which Mr. Davis referred. He thought for a time the phrenic recurrent union had succeeded, but he had lost sight of her, and it was evidently a failure. Therefore only 1 of the 5 cases from a surgical point of view was successful. Unless the paralysis was of very short duration it was unlikely that a surgical success would be attained.

When he reported these results in 1939 he suggested that from a practical surgical point of view they might get all they wanted in relieving the patient's

respiratory obstruction by fixing one of the cords in an abducted position. The operation he then suggested was to expose the arytenoid cartilage, abduct the vocal process, and fix it in the abducted position. In order to do that an incision was made down to the pyriform fossa by retracting the ribbon muscles forward and incising the inferior constrictor along the posterior edge of the thyroid ala. It was possible thus to expose quite easily from the outside, without opening the pharynx, the crico-arytenoid joint, which was opened and the arytenoid was exposed. The posterior edge of the ala should be excised.

The difficult part was to drill a hole in the arytenoid cartilage in which a suture was put near the vocal process to draw the vocal process out. The arytenoid cartilage was fixed in abduction by drilling two holes in the thyroid ala through which the ends were passed and tied outside the ala. Mr. Archer gave him the opportunity of doing that by sending to him from Manchester in 1942 a woman aged 40 who had compensated mitral stenosis and had had a thyroid operation, and eighteen months later a tracheotomy on account of double abductor paralysis causing stridor and distress. He carried out the operation described, and within a few days the tracheotomy tube was withdrawn and she breathed comfortably. She had written later stating that she was quite comfortable and had a good voice.

It was important that nothing should be done to disturb the intact laryngeal mucosa, and that was why all the operations devised for excising the cord were failures; one simply replaced the paralysed cord by a fixed scar. He had one patient, a woman from the North of England, who had a palsy with a tracheotomy, and she proved to be a person with acromegaly. In carrying out the operation the arytenoid cartilage became dislocated and he removed it altogether and fixed the cord, as he hoped, in an abducted position. In that case the relief was short-lived; she did get rid of the tracheotomy tube, but it had soon to be replaced. But on the basis of the first case the first method seemed to him quite a practicable one.

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GAVIN LIVINGSTONE recommended the clinical use of the electro-myograph as an aid to diagnosis. A long bipolar needle was inserted through a laryngoscope under local anæsthesia into the adductor and abductor group of muscles and the nerve impulses reaching the muscles were recorded.

In one case of apparently complete paralysis of the cord, the myograph showed normal nerve impulses coming through, but no movement was seen—the condition not being due to a nerve lesion.

There was no real technical difficulty in the needling, but the electrical recording and cathode ray amplification needed expert supervision.

T. B. LAYTON said that he liked the term "idiopathic" better than "paralysis of unknown origin". He wondered whether there were such things as idiopathic paralyses of the larynx and would suggest that all these cases called idiopathic were really cases of fixed joints. An arthritis of the joint

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caused the cord to be fixed during the acute stage, from which it recovered. He had seen one such case in a young doctor who had been told by another medical man that he had an idiopathic paralysis of the cord. This patient had been spending a winter holiday in Switzerland, and after playing in hot sunshine he was seized with a chill as the sun went down behind the mountains and he felt a severe pain in his neck and a sensation of frightful coldness. From that moment he became hoarse. The speaker suggested to him that what was wrong was a fixed joint, not a paralysis of the cord, and that it might come right and so it proved. A case of undoubted paralysis of the cord was certainly a serious, and probably a grave, lesion.

LIONEL COLLEDGE in reply to a question as to what sort of voice these people had after operation, said that in the woman whose case he had described the voice was a little rough but strong. Generally the patients with palsies had normal voices after a certain time for adaptation. They adapted themselves to talking with one cord, and the voice, perhaps with a little speech therapy, became normal.

J. ANGELL JAMES described the case of a soldier who had been wounded by a mortar bomb, a fragment of which had entered his neck through the right posterior triangle. The right vocal cord was completely paralysed, and a skiagram showed a fragment measuring 4 mm. by 2 mm. in the neighbourhood of the right transverse process of the sixth cervical vertebra. He had considerable discomfort in the neck and surgical intervention was thought justifiable. The carotid sheath was exposed and the fragment found embedded in the medial half of the vagus nerve. The fragment was removed and the sheath repaired and it was hoped that there might be regeneration of the nerve and recovery of the vocal cord. A year later he wrote that his voice had completely recovered, but only two days ago the man came to be seen and the cord was still paralysed.

THE PRESIDENT said the discussion had proved extremely interesting. Cases of bilateral laryngeal paresis were fortunately very uncommon. Unilateral paresis rarely gave trouble apart from loss of voice for a short period. The voice cleared when the other cord compensated but the paresis usually remained complete. He had in mind two ministers both of whom have unilateral vocal cord paresis and yet they have apparently normal voices. They were both voiceless for a short period only. In one case of sudden onset a bilateral paresis an urgent tracheotomy had to be performed and the patient (who was a jeweller) made his own tracheotomy tube with a small valve across the mouth controlled by a fine "bowden" wire so that he could speak normally without closing the tube with the finger.

Following on the publication of Dr Irwin Moore's paper in 1923 (*Jnl Laryn & Oto*, xxxviii, 236) he (the President) had tried the anterior operation. One case was almost successful but he split the cartilage in the middle line and by some mischance one cord was replaced rather below the other. The result was quite good except that the voice was what might be called a forced whisper only.

He had tried grafting the anterior end of the cords but without success although one case gave quite good results for about a year. He had only tried

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the posterior route once and although the result seemed quite good the patient had a lot of stridor and thought he was better with the tracheotomy tube.

The President agreed with Mr. Layton that some of these so-called idiopathic pareses were really joint infections.

MAXWELL ELLIS, in reply, agreed that "idiopathic" was not a satisfactory term, but at least they knew what it meant. It was very interesting that Mr. Colledge in 1939 should have embarked on the precise procedure that King described in the same year with a report of 24 cases. King did not bore a hole through the vocal process, because that was a difficult procedure technically. It caused fracture and was not easy to carry out. He ran the suture round the inner side of the vocal process and then did precisely what Mr. Colledge had described. The point was not to enter the larynx; if one did scar tissue formed. The second case which Mr. Colledge described followed the technique which Kelly employed in America.

Some speakers had suggested that recovery was an instance of functional not anatomical, cure. Undoubtedly a number of these unilateral cases did resolve and the cord returned to normal.

If Mr. Layton had put his question before Mr. Livingstone had spoken he would not have known how to answer it, but Mr. Livingstone had described an electro-myographic method of detecting the response of a nerve, and that might distinguish between cord paralysis and joint fixation. Without being too scientific and dogmatic he felt sure Mr. Layton would agree that on the basis of clinical experience, while there were a number of things not very easy to describe or define, one might be quite sure that one was dealing with a particular condition, generally on the basis of repeated examinations at different times.

The whole point of the Kelly operation of removing the arytenoid was to give a good airway posteriorly and to preserve a fairly good voice.

The President seemed to have gone the rounds of these various operations and he would have liked to have heard him speak on them at greater length.

MACDONALD CRITCHLEY, also in reply, said that he would like to make a plea for a most meticulous examination of the nervous system in all obscure cases of laryngeal palsy, because such might be the first sign of a tabes or of several other neurological conditions. As a neurologist one was often asked to see cases of paralysis of the larynx combined with lesions of other cranial nerves. Such cases were probably due to a virus infection. There was no reason why there should not be a virus affection of one single cranial nerve, e.g. the vagus, or recurrent laryngeal. Bell's palsy was probably an example of such. He had no doubt that members were also familiar with cases of recurrent laryngeal palsy in returning prisoners of war from Japan. Many showed signs of nutritional deficiency with bilateral blindness, deafness, dysæsthesia of the extremities, and recurrent laryngeal palsy.

## LETTER TO EDITOR

TO THE EDITOR, *Journal of Laryngology and Otology*.

DEAR SIR,

I hope to consider a reinvestigation of the phenomena associated with bone conducted hearing. In particular I am interested in those paradoxical cases in which bone conduction is grossly diminished or absent, whilst air conduction remains comparatively good. This is referred to by many authors, but I must confess I have never, in the course of ten years audiometry, encountered such a patient.

Dederding, *Acta Oto-Laryngologica*, Supplementum X, page 20, says :

"In many patients a remarkable circumstance with respect to bone conduction was observed, namely that it was abridged, indeed had quite disappeared, together with a fully preserved hearing of whisper, and comparatively good air conduction."

Unfortunately all reports such as these are based on tuning fork tests and the whispered voice, and for various reasons I consider these unreliable. In particular, masking was neglected.

I should be very grateful if you would publish this letter in the *Journal of Laryngology*, with a request for any information which our colleagues can supply. More precisely, I shall be very grateful if any otologist can give me details of any patient he has seen with this condition. What tests were applied and what suggestions can he make to explain the condition?

Yours sincerely,

ALEX. TUMARKIN.

May 7th, 1946.



# The Journal of Laryngology and Otology

(Founded in 1887 by MORELL MACKENZIE and NORRIS WOLFENDEN)

June 1946

## THE RÔLE OF MECHANICAL AND ANATOMICAL FACTORS IN THE PROBLEM OF TONSILLAR FOCI

By DR GEORGE RÉVÉSZ (Budapest)\*

THERE is scarcely any branch of medicine uninterested in the problem of tonsillar foci. No doubt single organs or organ systems or the whole organism may become diseased in association with, or owing to, acute or chronic tonsillar processes. The question however which of the chronic inflammations play the part of a focus, further their gross and microscopic, anatomical and pathological basis is to date much disputed. The survey of the referring literature has led to contradictory theoretical and practical results, wherefore I believe that still much accurate research is needed to find a definite and conclusive answer. First of all, the problem has two different aspects from the viewpoint of the practitioner and the laryngologist respectively. The practitioner regards the illness as a whole, he seeks for the ultimate cause and observes the complications occurring unexpectedly on the basis of the primary disease, whereas the laryngologist is given a momentary picture only and his role consists in stating that the suspected focal infection is present and in removing the focus. Whether or not he was right may be seen from the result of the operation, naturally if the other sources of infection had been excluded. According to a classical concept focal infection is a pathologic process due to local and latent or clinically minute infections in remote organs. The harmful agent "bacterium toxin" deriving frequently from a microscopic primary infectious focus enters in certain periods into the blood or lymph circulation and causes, through its toxic effect, general and organic symptoms according to the localization and extension of the

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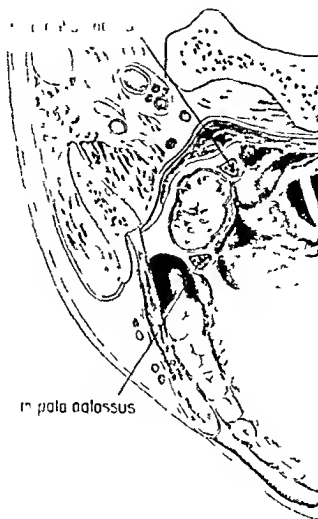


FIG. 1

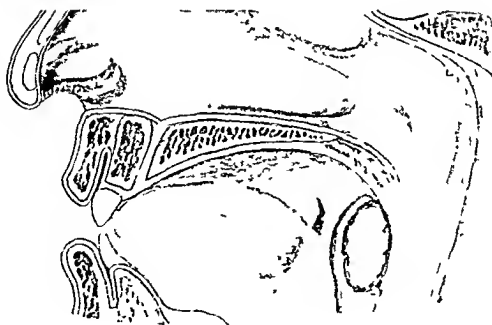


FIG. 2.

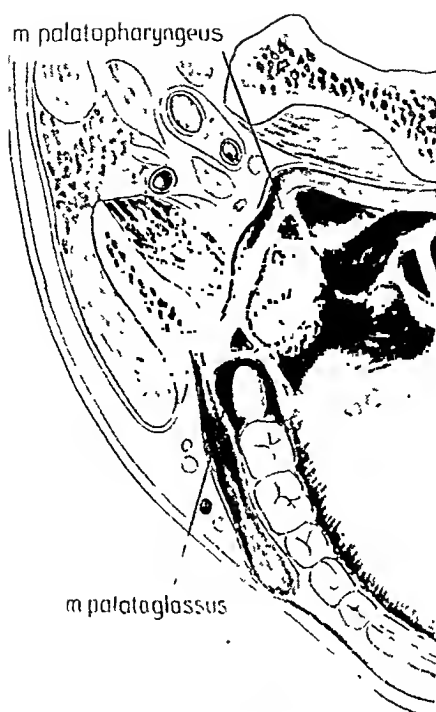


FIG. 3.

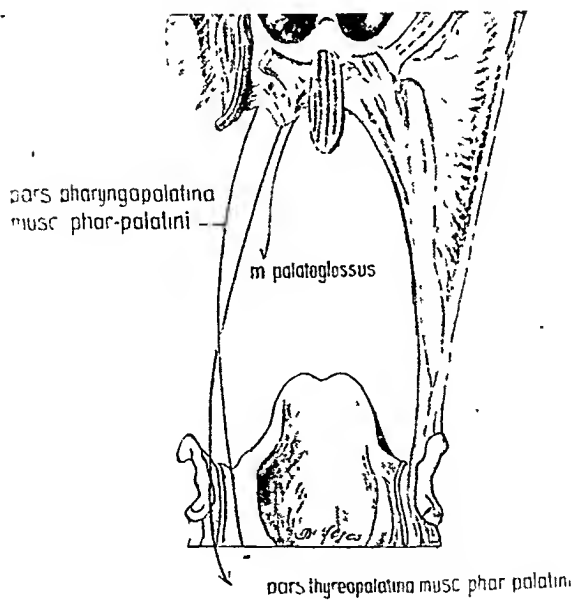


FIG. 4.

## Factors in the Problem of Tonsillar Foci

of the tonsils to their base by means of a very hard tissue is a frequent observation in the course of operation of patients having a history of repeated inflammations. In contradistinction to this, there is no marked redness or œdema in the pillars and the patient has no complaint beside the local ones. It is to be stressed that children and young individuals have nearly always movable tonsils whether they are large or small, deep or superficial lying, though the scar formation following on peritonsillar abscesses often cause fixation. The peri- and paratonsillar processes have doubtless a rôle because they act as transferring processes in allergic conditions or infections spreading over the whole organism. The adhesion symptoms mentioned above may be just as important as phlegmonous processes of this area attended by manifest symptoms. I think one is justified in assuming that localization or generalization of the process depend on the immuno biologic conditions, constitution of the organism, species and virulence of the bacteria rather than on the local alteration. The size of the tonsils, their fixation, the content of the crypts, their open or closed state, intracapsular phlegmonous processes, may be an additional factor in developing a general infection. They can, however, hardly determine it. Probably the simultaneous action of several components may account for the focal infection and the changes following thereafter.

There is beside the abovesaid still one factor which has not been duly emphasized in my opinion: the lodging of the tonsils between the palatal arcs and the rôle of the mechanical factors.

Regarding the problem from this viewpoint I observed that in all cases in which the assumption of a focal infection was right as seen from the improvement ensuing after tonsillectomy the removed tonsils had been found though pathologic and showing some of the alterations dealt with above, lodging deep between the palatal pillars. It is general knowledge that the organs located in the mouth and the pharynx are, under physiological conditions, steadily exposed to manifold pulling and pressure effects acting in various directions. The actual state of the tonsils and their contents depends on their size, location and occasional fixation.

In their normal position the tonsils lie rather impacted between the palatal pillars directly upon the pars buccopharyngea of the superior constrictor muscle whereby they are continuously under the effect of muscle contractions whenever the latter occur, e.g. with deglutition. Thus they will be dislocated toward the isthmus by the contraction of the muscle constrictor sup. pharyngis. Contraction of the stylopharyngeus results in pulling the tonsils laterally. Similarly, there occurs a lateral movement of the tonsils which is due to the simultaneous contraction of the palatoglossus and palatopharyngeus muscles while the two palatal pillars are, in the case of deep seated tonsils, brought nearer to each other whereby the surface of the tonsils becomes nearly separated from the oral cavity. Occasionally there is another relation of the tonsils to these two muscles

present characterized by that imaginary line connecting the middle points of the two muscles crosses the deepest point of the tonsil or runs laterally from its centrum: in this case the contraction of these muscles results in a dislocation of the tonsil toward the oral cavity. The latter fact has an importance to be assigned to it, likewise from anatomical and physiological, and from pathological viewpoint as well with a special regard to the explanation of focal infections.

The tonsil dislocated toward the oral cavity during the buccal stage and at the initial pharyngeal stage of deglutition undergoes a pressure increase coming about by elevation of the tongue and medial dislocation of the lateral pharyngeal walls as a result of the contraction of the mylohyoides, hyoglossus, and the constrictor pharyngis superior, palatoglossus and palatopharyngeus respectively. At the last stage of this first deglutition period the contracted tongue margin rolling backward encounters the medially dislocated tonsil whereby the tonsil contents will be expressed as can be demonstrated in the way described below.

The case of the deep-seated tonsil is quite different since the two pillars come in close contact and effect a thorough separation resulting in that the tonsillar content finds its way in the direction of the minimum resistance i.e. toward the capsule because the effect of the palato-glossus and palato-pharyngeus coming nearer to each other through their contraction is enhanced by the augmented intra-oral pressure hardly neutralized by the weak bucco-pharyngeus acting from without. An additional factor to this mechanism is supplied by a slight torsion of the tonsils about an imaginary frontal axis. I have demonstrated by roentgen examinations that the palato-pharyngeal muscle does, according to its anatomical architecture and the periods of deglutition, accomplish a double movement. During the buccal period it moves forward to the centrum of the tonsil, during the pharyngeal one it displays a vertical movement as a sign of the fact that the inferior mobile part of the pharynx is, owing to the contraction of the stylo-pharyngeus, constrictor pharyngitis medius and inferior, dislocated upward, toward the fix point. Being rather adherent by way of its capsule, to the muscles lodged in both pillars the tonsil accomplishes, in the second deglutition period characterized by the relaxation of the palato-glossus, the abovesaid torsion due to the contraction of the palato-pharyngeus.

In order to provide conclusive evidence of these facts I injected into the crypts of the tonsils to be removed a rather viscous opaque material with the aid of a duly adapted syringe. In all cases of undep-seated tonsils the crypts became empty after a few deglutition acts whether the tonsils were large or small. In the cases of deep-seated tonsils the opaque material remained in place even after a series of deglutitions and could be expressed mechanically. Thus the importance of the anatomical position of the tonsils is obvious.

## Factors in the Problem of Tonsillar Foci

Later on I became concerned with a visible control of the emptying of the crypts. To achieve this Hirschmann-Valentin's endoscope was introduced through the anaesthetized inferior nasal meatus so as to be placed behind the uvula and the crypts were filled with a blue liquid sharply contrasting with the hue of the mucosa. The tonsils lying superficially were always pushed by the initial deglutition movements towards the oral cavity and the injected material appeared in the openings of the crypts. After the deglutition act the blue material was no longer present, obviously it has been obscured by the tongue rolling backward. In the cases of deep seated tonsils the blue dye scarcely, if at all, appeared.

The followed data of the ectomized patients showing improvement or ceasing of the complaints are in full harmony with the results of the experiments reported above.

The following experiment has been instituted to express numerically the pressure exerted by the palato glossus and palato-pharyngeal muscles. A small metal globe was placed upon the muscles about at the middle of the tonsils on each side. By latero lateral fluoroscopy could be observed that in the first period of deglutition the metal bodies came nearer to each other and hereby also to the middle points of the tonsils, later on they returned to their original position. Further I could observe that the palato pharyngeus resp the metal body placed upon it accomplished also a vertical movement as a sign of its participation in the contraction of the middle and inferior constrictor muscle. To demonstrate these dislocations films have been made with a long exposition time whereby the dislocation could, without neglecting the distance between metal body and light source or film respectively, be measured as being 3 to 5 mm.

Presuming that the tonsil is seated in the middle between the two pillar "muscles" the power exerted on the tonsil by the muscles in full contraction is to be calculated. If only these two muscles act upon the tonsil from two opposed directions, further if the longitudinal imaginary axis of both muscles lie in the same plane the power exerted by each are equal and oppositely directed. Thus it will suffice in following to examine one of these muscles only. We will regard the muscle as a thoroughly flexible thread free of friction. The pressure exerted by such a thread upon the bodies being in contact with it is determined by its curvature and the power of traction appearing in it. The power of traction is directly proportional to the pulling tension and the surface 'superficial extent of the cross section'.

$$P = Fp$$

In the formula  $P$ =power,  $F$ =superficies,  $p$ =tension

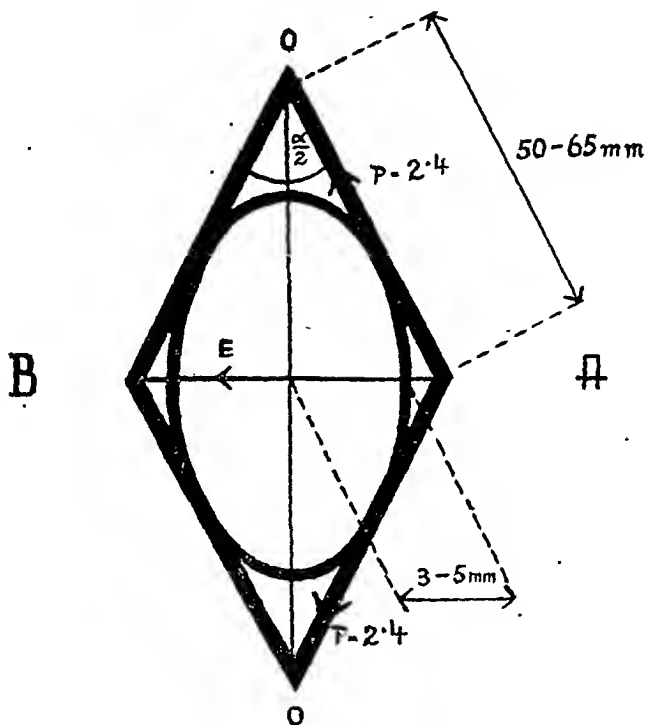
I measured the area of the cross section of both muscles and found an average of approximately  $0.4/0.39/\text{cm}^2$ .

At an earlier time experiments have been performed to determine the absolute muscle power as calculated for the surface unit. Departing from

# George Révész

the maximum muscle tension several authors attained at an estimation which yielded an average of  $6 \text{ kg/cm.}^2$ . The substitution of these values in the formula gives the result :

$$P = 0.4 \text{ cm.}^2 \cdot 6 \text{ kg/cm.}^2 = 2.4 \text{ kg.}$$



The figure allows a well understandable explanation. Side A should represent the palato-pharyngeus muscle, side B the palato-glossus. The ellipsis lying between them represents the tonsil, O and O the approached muscle fixations. The power E acting from A can be determined by means of the formula :

$$\text{Since } \sin \frac{\alpha}{2} = \frac{E}{2P} \quad \frac{E}{2P}, E = 2P \sin \frac{\alpha}{2}$$

$$\sin \frac{\alpha}{2} = 2.0 \cdot 06 = 0.12,$$

$E = 0.12 \cdot 2.2 \cdot 2.4 = 0.576 \text{ kg.}$  "Considering the lowermost limits of the values".

As to the pressure tension present in the cross section of the tonsil, vertical to the resultant of the muscle pressure :

$$P = \frac{E}{F}$$

where E means the pressure determined above, F=superficies.

The cross section of the tonsil being approximately an ellipsis its

# Factors in the Problem of Tonsillar Foci

area can be calculated from the known axis lengths they measuring 18 to 20 and 9 to 10 mm respectively

$$F = ab\pi = 1271 \text{ cm}^2$$

"a and b mean the half axes"

According to the general formula  $E = \Gamma p$ ,  $p = E = 0.45 \text{ kg/cm}^2$

The pressure tension determined in this way is indeed only an approximation the elasticity resp firmness of the tonsil having been entirely neglected. Virtually the tension measured near the centrum is different from that appearing on the surface

It is obvious from the calculated numerical values that a change in the anatomic condition that is when the imaginary straight line running through the two muscles which act on the tonsil from both sides does not cross the accurate middle point of the tonsil whereby it does act on a part of the crypt system different from its centrum the liquid contents which are practically incomprehensible will be dislocated toward the mouth cavity or the capsule. In the latter case the movement of the liquid may account for a focal infection occurring with a mechanism described in the introduction of this paper

## Summary

Beside the symptoms known to date the following factors deserve attention from the viewpoint of the tonsillar focal infection

1 The site of the tonsil between the pillars the deep site being an important factor

2 The pressure exerted on the tonsil in the course of deglutition by muscles especially those in the anterior and posterior palatal pillars which express the contents of the crypts

3 The pressure exerted by these muscles amounts to about  $0.6 \text{ kg/cm}^2$  representing

4  $0.45 \text{ kg/cm}^2$  pressure tension on the central part of their cavity system i.e., on the imaginary plane lying in the axis of the tonsil

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# ON THE RELATIONSHIP BETWEEN RADIOLOGICAL APPEARANCES AND PROOF- PUNCTURE FINDINGS IN SUSPECTED CASES OF INFECTION OF THE MAXILLARY ANTRUM

By J. CHALMERS BALLANTYNE, R.A.M.C.\*

IN this paper, an attempt has been made to assess the value of X-rays in the diagnosis of pathological conditions of the maxillary antrum. The results of seventy-five consecutive and unselected cases are recorded in tabular form. It had been hoped to collect a hundred such cases, but an unexpected posting made their completion impossible and it was felt that the result would be more valuable if the films of only one radiographer and the reports of only one radiologist were used.

The remarks under "X-ray Appearances" are exactly as reported to me by the radiologist. The results of "Proof-Puncture Findings" require further explanation. These latter are recorded in five different grades:

- (a) No pus—where the solution used for lavage was returned completely clear.
- (b) Few flakes only—where only a few minute flakes of inspissated pus or epithelial debris were returned.
- (c) A single "plus" sign (+)—where only a small amount of pus, cleared by one washout (i.e. one syringe full) was obtained. This was usually tenacious in consistency and yellowish in colour.
- (d) A double "plus" sign (++)—a single large blob of pus or pus as in (c) above requiring two or three washouts to clear.
- (e) A triple "plus" sign (+++)—more than (c) or (d) above—usually a very large quantity, often foul-smelling, fragmented and greenish-grey in colour.

## Results

The results of these investigations are shown in the table. Seventy-five cases are recorded. Of these, 9 (Nos. 2, 5, 10, 12, 13, 24, 25, 30, and 31) showed negative radiological appearances, but in each of these it was felt that the clinical manifestations warranted a diagnostic proof-puncture. In none of these cases was there any evidence of pathology on lavage.

\* From the 94 (Hamburg), British Military Hospital, B.A.O.R.

# Suspected Cases of Infection of Maxillary Antrum

Of the remaining 66 cases, in which positive findings were recorded on X-ray examination, 58 showed evidence of sinus pathology on puncture and lavage. In the remaining 8 (Nos 28, 29, 39, 40, 43, 44, 56, and 70), no pus was detected. In one of these (No 44), however, though there was no evidence of active infection, a clear yellow fluid was obtained by puncture of the right antrum before lavage was begun. The X-ray report in this case was "Right antrum—circular opacity". Of the remaining 7 cases with positive radiological and negative proof-puncture findings, 2 more (Nos 39 and 43) were reported as "Rounded opacity ? polyp", and it is possible that a polyp was present in each though not entered by the trochar and cannula. Of the remaining 5, 3 (Nos 29, 40 and 70) showed radiological appearances suggestive of mucosal thickening only.

Of the 58 cases showing positive proof-puncture findings, 48 showed frank pus, the remaining 10 showing a "few flakes only"—evidence of old or quiescent infection of the antrum. The majority of those with frank pus (two thirds of the cases) belonged to the fourth grade (or double "plus" sign)—a single large blob of pus or tenacious, yellowish pus requiring two or three washouts to clear.

## Summary and Conclusions

There are recorded in this paper, the results of diagnostic proof-puncture of the maxillary antrum in 75 consecutive and unselected cases of suspected infection—irrespective of X ray appearances.

In 9 of these cases, it was felt that proof puncture was justifiable on clinical evidence, in spite of negative radiological reports. But in none of these was any evidence of infection found on lavage and it would appear reasonable to assume that sinus pathology will, in the majority of cases, give rise to detectable changes in the X-ray film.

Of the remaining 66 cases, in which there were positive radiological findings, 58 (or 88 per cent) showed evidence of infection on proof-puncture and lavage. Of these latter, 48 (or 83 per cent) showed frank pus, the remaining 10 (or 17 per cent) showing a "few flakes only"—evidence of old or quiescent infection.

Eight cases remain in which there were positive radiological, and negative proof-puncture, findings. In 3 of these, the radiologist reported the possibility of a polyp and in one a clear, yellow cystic fluid was actually withdrawn. In only 5 cases of the whole series could the radiological appearances be attributed to a thickening of the mucous membrane and in three of these this was, in fact, reported by the radiologist.

The results are encouraging and would suggest that a good X ray film, interpreted by an experienced radiologist, is the most reliable adjunct to the clinical diagnosis of infections of the maxillary antrum.

In conclusion, I wish to express my gratitude to Mr R. Scott Stevenson my chief during the earlier part of these investigations, for his

# J. Chalmers Ballantyne

encouragement and help; to Captain D. J. Roberts, R.A.M.C., Graded Radiologist, for his co-operation in the interpretation of the X-ray appearances; and to Sgt. Harrison, R.A.M.C., Radiographer for his excellent films. I would also like to thank Colonel W. Campbell for permission to publish this paper.

Case No.	X-ray appearances.	Proof-puncture Findings.
1	(R) Antrum opaque	(R) ++
2	Negative	(L) No Pus
3	Both antra opaque	(R) and (L) ++
4	(R) antrum—slight increase in density	(R) few flakes only
5	Negative	(R) No pus
6	(L) antrum—increase in density	(L) Few flakes only
7	(R) antrum opaque	(R) +++
8	Both antra slightly opaque	(R) and (L) few flakes only
9	(L) antrum—slight opacity	(L) few flakes only
10	Negative	(R) No pus
11	(L) antrum opaque	(L) ++
12	Negative	(R) No-pus
13	Negative	(L) No pus
14	(R) antrum opaque	(R) few flakes only
15	Both antra opaque	(R) and (L) ++
16	(R) antrum—slight increase in density	(R) ++
17	(R) antrum opaque	(R) ++
18	(R) antrum—slight increase in density	(R) ++
19	(R) antrum opaque	(R) ++
20	(R) antrum opaque	(R) ++
21	Both antra opaque—especially (L)	(L) ++
22	Both antra opaque—especially (R)	(R) ++
23	Both antra opaque	(R) and (L) +++
24	Negative	(R) No pus
25	Negative	(R) No pus
26	(R) antrum opaque	(R) ++
27	(R) antrum opaque	(R) +++
28	Both antra opaque	(R) and (L) No pus
29	(L) antrum—increased density of lower part	(L) No pus
30	Negative	(R) and (L) No pus
31	Negative	(R) No pus
32	(L) antrum opaque	(L) ++
33	(L) antrum—hazy	(L) ++
34	Both antra opaque	(R) and (L) ++
35	(L) antrum opaque	(L) +++
36	Both antra opaque (R) more than (L)	(R) +++ (L) ++
37	(L) antrum opaque	(L) +++

# Suspected Cases of Infection of Maxillary Antrum

38	(R) antrum—increased density	(R) +
39	(R) antrum—rounded opacity 2 polyp	(R) No pus
40	(R) antrum 2 mucosal thickening	(R) No pus
41	(R) antrum opaque	(R) ++
42	(L) antrum opaque	(L) ++
43	(R) antrum 2 polyp	(R) No pus
44	(R) antrum—circular opacity	(R) Cystic fluid No pus
45	Both antra opaque—more marked on (L)	(L) ++
46	Both antra opaque	(R) and (L) ++
47	(R) antrum—increased density	(R) ++
48	(L) antrum opaque	(L) +++
49	(R) antrum—increased density of lower part	(R) +
50	(R) antrum—slight haziness	(R) few flakes only
51	Both antra opaque	(R) and (L) +++
52	Both antra opaque	(R) and (L) ++
53	(L) antrum opaque	(L) +++
54	Both antra opaque (R) more than (L)	(R) ++
55	Both antra opaque (R) more than (L)	(R) ++
56	(R) antrum opaque	(R) No pus
57	(R) antrum—slight haziness	(R) +
58	(L) antrum opaque	(L) ++
59	Both antra opaque	(L) +
60	(R) antrum opaque	(R) ++
61	(L) antrum opaque	(L) ++
62	(L) antrum opaque	(L) ++
63	(R) antrum—increased density	(R) few flakes only
64	Both antra opaque	(R) and (L) ++
65	Both antra opaque	(L) ++
66	(R) antrum opaque	(R) ++
67	(L) antrum opaque	(L) +
68	Both antra opaque	(R) and (L) few flakes only
69	Both antra opaque	(R) and (L) few flakes only
70	Both antra slightly opaque	(R) and (L) no pus
71	(L) antrum opaque	(L) ++
72	Both antra opaque	(R) and (L) ++
73	(L) antrum opaque	(L) +
74	(R) antrum opaque	(R) few flakes only
75	(R) antrum opaque	(R) +++

## CLINICAL RECORD

### CASE OF BILATERAL FRONTAL SINUSITIS WITH OSTEOMYELITIS OF THE FRONTAL BONE AND LEFT ANTRAL SINUSITIS, TREATED WITH PENICILLIN

By DONALD WATSON (Bradford)

*Frank Spencer. 13 years.*

#### HISTORY.

24.9.46. This normally healthy boy has had a headache for five days. The headache followed a cold and diving in a public swimming bath. Three days ago his forehead above the left eye was slightly swollen and he had a temperature. Since then the swelling and headache have become worse, and his temperature yesterday was  $103^{\circ}$ .

#### *Condition on admission.*

*Temperature* 99.6. *Pulse* 116. *Respiration* 22. *Violent frontal headache.*  
*Facial appearance:* Great deal of swelling of the left eyelids, particularly the upper, with œdema of the left side of the forehead, extending almost to the hair margin, over to about the centre of the right supraorbital margin. The frontal bone was exquisitely tender to touch over and slightly beyond the œdema.

*A.R.* Slight amount of pus in the left middle meatus, nil in right.

*Mouth:* nil.

#### *Diagnosis.*

Acute bilateral frontal sinusitis, with osteomyelitis of frontal bone and left antral infection. To-night, 6 p.m. *Temperature* 102.8. *Pulse* 108. *Respiration* 22.

#### *Treatment.*

Penicillin 1 c.c. 10,000 units every three hours.

B.D.H. Ephedrine Co. spray twice daily.

Menthol inhalations and head light bath every four hours.

#### *X-ray report.*

25.9.46. Sinuses: There is diminished translucency of both frontal sinuses, consistent with infection. The supramedial margin of the right orbit is rather hazy, but there is no evidence of bone destruction, and I think this is from the sinusitis. There is also diminished translucency of the left antrum. No fluid level visible.

#### *Operation.*

An abscess developed in the mid-line of the forehead two inches above the glabella. This was opened and 1 c.c. of pus evacuated. Small gauze drain. Frontal bone exposed and explored—no fistula into frontal sinus found and no visible change in bone.

# Clinical Record

26 9 46 Not much change in condition of left eye, slightly more pus in left middle meatus Headache easier General condition much improved Pathological report on pus—*streptococcus hæmolyticus*

27 9 46 Condition much better Temperature fallen to normal at 10 a.m. Oedema of eye and forehead much less

A.R. Great deal of pus in left middle and common meatus No pus in right nostril

30 9 46 Swelling of forehead and left eye practically gone No pus seen in nose Temperature normal since 27 9 46

1 10 46 Both antra explored with needle—no pus present

5 10 46 Penicillin discontinued Total given 85 c.c. (850,000 units)

## X-ray report

8 10 46 Sinuses and frontal bone There is still a slight degree of diminished translucency of both frontal sinuses The walls of the cell spaces are thin hazy and somewhat indistinct No visible fluid levels No evidence of bone destruction The antra are normal in appearance The appearance is consistent with a subsiding infection of the frontal sinuses

9 10 46 Temperature has been normal since 27 9 46

17 10 46 Discharged from hospital

## DISCUSSION

The left frontal sinus had a small upward extension near the mid line where the osteomyelitis developed, no doubt due to thrombosis of anastomosing vessels of the muco periosteum lining the sinus and the diploe of the frontal bone

I have seen six cases of osteomyelitis of the frontal bone One case died of meningitis (15 years ago) due to infection from pus formation on the inner aspect of the bone (*Pott's puffy tumour*) Armed with penicillin I risked the Pott's puffy tumour—the external abscess suggested it might be present

Had I been younger, I have not the slightest doubt that I should have plunged into major surgery when I first saw this case with the consequent disfigurement of the boy In the middle of his forehead is a small transverse scar, his only mark which I trust will become the central part of one of the lines that develop in the brows of all thinking people

## COMMENT

This case demonstrated the efficacy of penicillin in both osteomyelitis and sinusitis The improvement in the boy's general condition after 24 hours was amazing

# CLINICAL NOTE

## A CASE OF RESPIRATORY INCO-ORDINATION

By CLIFFORD EVANS and DAVID HEWSPEAR, D.A. (London)

THIS recruit was first seen by one of us (D.H.) during a routine sick-parade five weeks after he had joined the Army. He complained of "inability to breathe through his nose". Medical treatment was tried, but failed.

He was then referred to the E.N.T. Department of a Military Hospital. (Seen by C.E.) The only abnormality present was a gross narrowing of the nasal airway posteriorly. (On looking back—due to disuse.)

The size of the nasal airway was increased surgically, so that when healed a No. 9 Magill intratracheal catheter could be easily passed through either nostril. (Shown in the attached photos.) But still he was unable to breathe through his nose.

At this stage his social history was gone into and it was found that he began life in an orphanage and from the age of four to fourteen years was in the care of professional foster parents (with two other orphanage boys). These were very unhappy years. At the age of fourteen, until he joined the Army at the age of eighteen years, he was employed by a farmer and was on duty from 6 a.m. to 6 p.m. for seven days a week. For the first time in his life he finds himself having an equal chance with his fellow men, and he is anxious to become a regular soldier.

He had been a mouth breather for as long as he could remember. In view of his psychological background we then considered whether the condition might be some form of neurosis so it was decided to test his respiration whilst under anaesthesia. The patient was most co-operative throughout as he was anxious to improve himself.

First, surface anaesthesia was tried (10 per cent. Cocaine HCl); but no appreciable difference was detected. Then a general anaesthetic (gas and oxygen) was administered (by D.H.). It was found that whilst under deep anaesthesia (stage 3) nasal breathing occurred easily and freely in spite of the mouth being completely occluded with strapping. As soon, however, as the patient became light (and before he was conscious) the "nasal obstruction" returned and he became blue. This experiment was repeated several times. Next, blind (nasal) intratracheal intubation was performed, and the intracheal tube was slowly raised and lowered as the anaesthetic was deepened and lightened and it was found that a sphincter-like spasmodic obstruction occurred at, or just above, the level of the glottis, being particularly obvious under very light anaesthesia.

This appears to suggest to us some form of muscular inco-ordination due to a long-standing psychological maladjustment.

He was transferred to a centre where he could obtain remedial breathing exercises. When seen six weeks later, he showed great improvement.

A search of the available literature failed to find other cases of a similar type or a description of this condition.

A CASE OF RESPIRATORY INCOORDINATION—  
CLIFFORD LYANS AND DAVID HEWSPER







# SOCIETIES' PROCEEDINGS

## ROYAL SOCIETY OF MEDICINE—SECTION OF OTOTOLOGY

March 1st, 1946

President—A J WRIGHT, F.R.C.S.

### Discussion on the Chemotherapy of Meningitis Secondary to Infection of the Ear and Nasal Sinuses.

#### OPENERS

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OTOGENIC meningitis and meningitis secondary to infection of the nasal sinuses have much in common. In both the bacteriology is similar, in both the meningitis may be complicated by abscess formation and in both the problems of treatment are in many respects the same. We therefore propose to discuss these two groups of cases together. We also include certain cases where the meningitis arose not from a frank sinusitis but as a result of a fracture involving the nasal sinuses (Table I).

TABLE I

A SERIES OF 37 CASES SECONDARY TO INFECTION OF THE EAR AND NASAL SINUSES ANALYSED ACCORDING TO AETIOLOGY AND BACTERIOLOGY

Source of infection	Pneumococci	Streptococci	Staphylococci	Mixed	<i>H. influenzae</i>	Total
Otitis	13	4	1	2*	1	21
Sinusitis	6	3	0	0	0	9
Fracture through sinuses	6	1	0	0	0	7
Total	25	8	1	2	1	37

\* Pneumococci + *Staph. aureus*, (ii) Streptococci + *Staph. aureus*

Some of our patients were referred to us directly as cases of meningitis. Often this was because the bacteriologist who examined the C.S.F. identified Gram positive organisms and made it his business immediately to get in touch with the clinician in charge of the case and urge treatment with penicillin. The site of the primary focus of infection was often discovered only after careful assessment of the history and clinical and radiographic examinations. Others were first admitted to hospital, either at Oxford or elsewhere, for treatment of the nose or throat. In these the meningitis usually developed while they were under observation. In those cases where the meningitis followed a fracture through the sinuses, some of the patients were admitted to hospital

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on account of their head injury, while in others the head injury preceded the meningitis by a variable interval and was only discovered by a study of the history.

From the practical point of view cases with this ætiology fall into three main groups: (1) Those in which no organisms are recovered from the C.S.F.; (2) those due to organisms which are either relatively or totally resistant to penicillin; (3) those due to infection by penicillin-sensitive organisms.

The first group includes those cases of relatively low-grade infection sometimes called "sterile" meningitis and also cases of intracranial abscess where bursts of mild meningitis develop during the course of the illness. These cases usually respond well to sulphonamides and unless an abscess is present no other form of chemotherapy may be needed. The patients must, however, be carefully watched and their progress checked by repeated bacteriological examination of the C.S.F., since fluid which is at first sterile may later give a positive culture (Smith *et al.*, 1946, Case 1). If the patient has received sulphadiazine before the lumbar puncture is done, cultures of the C.S.F. must be set up with para-aminobenzoic acid. They will otherwise probably be sterile when the true nature of the infection will be missed.

The second group is small but important. The predominating organisms are *H. influenza* and *B. proteus*. Fortunately these cases are not common as the mortality in this country has been high. Occasionally influenzal meningitis responds to heavy and prolonged dosage with sulphadiazine, while in America Alexander (1944) has achieved excellent results by the use of immune rabbit serum which is given in conjunction with sulphadiazine. Recently cases have been reported in which the infection has been controlled by intrathecal penicillin (Forgacs, Hutchinson and Rewell, 1945; Straker, 1945), and it appears that, at least with certain types, the resistance of *H. influenza* to penicillin is relative rather than absolute.

We have treated one case of otogenic influenzal meningitis.

CASE I.—R.I. 25486/44.

A baby of 8 months was one day noticed to have a thick purulent discharge coming from his right ear. He did not seem unwell at that time but five days later, the left ear also began to discharge. Eight days later he was admitted to the Ear, Nose and Throat Department of the Radcliffe Infirmary, and the following day a bilateral Schwartze mastoidectomy was performed. The right mastoid contained a fair amount of mucopus, but the left only showed some injection. Following operation the condition of his ears was uniformly satisfactory, but his temperature rose, and he was given sulphathiazole (3 grammes daily). For the next ten days his temperature was maintained at about 102°F. without the development of any physical signs, but on the eleventh day he developed a squint and on the twelfth day was found to have considerable neck stiffness. A lumbar puncture revealed a cloudy fluid but no organisms were seen on the direct film, and it was not until four days later that the organism grown on culture was identified as *H. influenza*.

During these four days, treatment with intramuscular and intrathecal penicillin was given in view of the previous lack of improvement on sulphathiazole. There was no clinical improvement throughout this period.

When the organism was reported as insensitive to penicillin, sulphadiazine

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(3 grammes daily) was begun, and the penicillin discontinued. Thereafter the child slowly improved, but one attempt to reduce the dose of sulphadiazine and another to discontinue the drug after three weeks, were quickly followed by clinical and bacteriological relapse. Finally the child made a complete recovery after having received sulphadiazine for seven weeks. At no time were any signs of drug intolerance detected.

The third group is the largest and most important. The commonest organisms are pneumococci and streptococci, both hæmolytic and anaerobic. Staphylococci are much rarer (Stewart, 1929, Weinstein, 1942). The predominance of pneumococcal over streptococcal infections in our series may be due to the fact that we were making a special study of pneumococcal meningitis at the time when these cases were treated, on the other hand, before the days of effective chemotherapy, many cases of pneumococcal meningitis must have died before admission to hospital. Our experience is still very limited especially with streptococcal and staphylococcal meningitis, but we will produce evidence that the nature of the organisms is of considerable practical importance. The bacteriology and ætiology of cases is shown in Table I. We have omitted those cases where the nature of the organisms was not proved by culture.

Except for meningococcal meningitis, which seldom requires treatment with penicillin, the treatment of meningitis due to penicillin sensitive organisms is essentially the same whatever the infecting organism. This may conveniently be considered under three headings: (1) Treatment of the leptomeningitis, (2) detection and treatment of a complicating intracranial abscess, (3) treatment of the primary focus of infection.

## I TREATMENT OF LEPTOMENINGITIS

We have recently described our methods in full (Smith *et al.*, 1946) but the most important points in what we consider the basic treatment of meningitis may be recapitulated. As a routine we use both intrathecal and systemic penicillin with sulphadiazine by mouth. Penicillin for intrathecal use is made up in a solution of 2,000 u./c.c. and given in doses of from 8,000 to 10,000 units during the first thirty six to forty eight hours. Injections should be given every twelve hours but thereafter daily injections are usually sufficient. The efficacy of dosage and treatment should be checked by daily bacteriological examination of the C.S.F. and estimation of its penicillin content, which, in a few patients, reveals that penicillin escapes unusually quickly from the C.S.F. In these the frequency of injections can then be increased so that a bacteriostatic concentration is constantly maintained.

The easiest and safest way of giving the intrathecal injections is by lumbar puncture. About 6 c.c. of C.S.F. is withdrawn for examination, and the penicillin then slowly injected. The injection should be frequently interrupted by aspiration of C.S.F. This insures that the needle is correctly placed and also dilutes and warms the solution. The lumbar route is only effective when the cerebrospinal pathways are patent. The earliest sign of their occlusion is a slowing in the flow of C.S.F. and difficulty in aspiration during the injection. This observation must be checked by repeating the tap in a higher space and using a wide bore needle since if it is confirmed it is an absolute indication for giving penicillin either by the cisternal or, preferably, by the ventricular route.

The intrathecal penicillin is supplemented by the oral administration of sulphonamides. Sulphadiazine, in doses of 12 grammes in twenty-four hours is at present the preparation of choice because it diffuses freely from the blood into the C.S.F. It therefore reaches all parts of the cerebrospinal pathways including any loculi that may be inaccessible to the penicillin. It is given to suppress the virulence of the infection and thus to help maintain the patency of the cerebrospinal pathways. In any case of meningitis treatment with sulphadiazine should be begun immediately as this will tide the patient over the interval that may elapse before treatment with penicillin is started.

Systemic penicillin is given either by continuous intramuscular drip or by intermittent three-hourly injections. The minimal daily dose is 120,000 u. in twenty-four hours, but in certain cases, for example in the presence of a frank septicæmia, this should be increased as much as 320,000 in twenty-four hours. We have no evidence that systemic penicillin alone can cure meningitis and its chief value lies in the control of the primary focus of infection and of a complicating septicæmia or pyæmia.

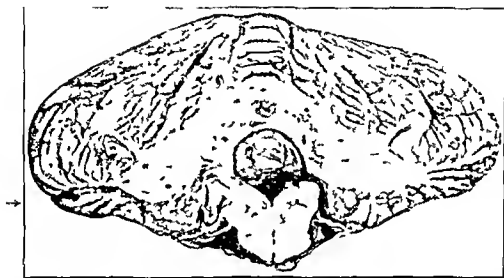
The intrathecal penicillin must be continued for at least five days, for although clinical and bacteriological improvement is usually obvious after three days, the cerebrospinal fluid has probably not been completely sterilized. 10 of the 37 patients in this series relapsed even after a full intrathecal course, and from our experience, if less than five days' treatment is given the proportion that relapse increases. There is also the danger that the relapse may be fatal and uncontrollable. Relapse is most common within the first forty-eight hours after the last intrathecal injection but may occur even while the patient is receiving daily lumbar injections. When this happens, either the solution in use has lost its activity, or penicillin is not reaching the site of infection, or is escaping from the theca unusually rapidly. Two of our patients relapsed even when convalescence seemed assured, and in two others isolated positive cultures from the C.S.F. were obtained without any concomitant clinical disturbance. Sulphadiazine should be given during the period in which the intrathecal penicillin is withdrawn as it provides a safeguard against uncontrollable relapse.

In a relapse, rise in temperature and recrudescence of headache and malaise precede the reappearance of cells and organisms in the C.S.F. by as much as twenty-four hours. The treatment of relapse does not differ from that of the initial attack and in our experience the prognosis as regards life and functional recovery is not altered, provided that each relapse is promptly recognized and treated. We would emphasize the need for vigilance and persistence in treating the severe relapsing case, as a complete cure can be obtained even when the illness lasts over three months.

Relapse may be due to inadequate treatment or to reinfection of the meninges either from the primary focus or from a small intrathecal fibrinopurulent collection. In otogenic cases, is relapse an indication for opening the mastoid? In only one of our cases did this prove necessary.

CASE II.—R.I. 5657/44. *Reinfection from the primary focus* (Smith *et al.*, 1946, Case VI).

A bricklayer aged 53 had a right mastoidectomy performed elsewhere following a six weeks' history of severe earache. The immediate post-operative



↑ FIG 1

*Case III*—Section through medulla and cerebellum showing a fibrino purulent collection within the sheath of the right eighth nerve continuous with a small abscess in the right lateral recess of the fourth ventricle (arrows) Such fibrino purulent collections are probably the commonest cause of relapses



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course was smooth except that he developed a complete facial palsy, but ten days after operation he vomited his temperature rose and he developed signs of meningitis. Lumbar puncture was performed and pneumococci (Type III) were grown on culture from the C S F. Treatment with sulphathiazole was at once begun and two days later he was transferred to Oxford. On admission his general condition was excellent and except for the complete right facial palsy there were no abnormal neurological signs. The mastoidectomy wound was healed and the ear was dry. Lumbar puncture revealed an almost clear C S F containing only 160 cells but pneumococci were once more grown on culture.

He was then treated with intrathecal penicillin and sulphadiazine but systemic penicillin was withheld. His progress was uneventful but eight days after his last intrathecal injection he relapsed and cultures of the C S F again became positive. He received a further course of intrathecal penicillin and sulphadiazine and again responded well. During convalescence he was seen by Mr Livingstone who advised re-exploration of the mastoid and a facial nerve graft.

At operation it was found that the original operation had been incomplete. Mr Livingstone's note states: "The antrum had never actually been reached. There were many mildly infected cells over the dura and lateral sinus. When the residual cells were removed, the sinus was found to be healthy, but in one place the dura of the middle fossa was covered with rough granulations, and these were thought to be the route of the entry of his meningeal infection." Cultures taken from this patch of granulations grew pneumococci.

The facial nerve was then freed from all residual cells and the defect repaired by a graft.

He made a permanent recovery from his meningitis and when seen a year later was free from symptoms except for a moderate right sided deafness of middle ear type. There was satisfactory recovery of the facial palsy.

The meninges more often become reinfected from a small intrathecal fibrino purulent collection as in the following case.

CASE III—*Reinfection from an intrathecal fibrino purulent collection* (Smith *et al*, 1946 Case VII)

A regular soldier aged 39 developed pneumococcal meningitis secondary to a right sided otitis media. Both the initial attack and a relapse were controlled by sulphapyridine but following the second attack he died from an inhalation bronchopneumonia. Examination of the brain revealed a collection of pus within the right auditory nerve which was continuous with a tiny abscess in the lateral recess of the fourth ventricle (fig 1).

Two of our patients whose meningitis was not primarily otogenic in origin developed a nerve type of deafness during the course of this illness. This deafness is presumably analogous to that so often seen in the past in meningococcal meningitis. In one of these patients at least, we presume the lesion was similar to that just described (fig 1) as her illness ran a prolonged relapsing course before she ultimately recovered.

CASE IV—R I 36553/44

The patient, a housewife of 52, was admitted as an emergency on the medical side on October 24th, 1945. About four weeks earlier she had caught a cold



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in the head and had had a slight cough but this had not interfered with her normal activities. At 8 o'clock the evening before her admission she had been visited by her daughter-in-law, who noticed no signs of ill-health, but during the night she vomited and became drowsy though restless. By the following morning she was semicomatose with neck stiffness and photophobia and with a temperature of  $102^{\circ}\text{F}$ . She was forthwith sent to hospital.

On admission she was extremely ill. She was stuporous but any attempt at examination provoked outbursts of silent struggling. Her neck was very stiff and Kernig's sign was positive. There were unequivocal signs of consolidation at the base of the right lung. Lumbar puncture showed an unusually purulent fluid (25,000 cells per c.mm.) which was swarming with pneumococci. Blood culture was also strongly positive.

Treatment was begun with intrathecal and intramuscular penicillin and sulphadiazine, but by the same evening the flow of C.S.F. was so sluggish that bifrontal burrholes were made and an intraventricular injection of penicillin given. Thereafter she steadily improved but on recovering consciousness was found to be deaf in the right ear and to have rapid poorly sustained nystagmus on looking to the left. She was also retentive of urine, and both ankle-jerks were absent.

On the eleventh day, while she was still receiving daily lumbar injections of penicillin, her temperature which had previously fallen, rose suddenly to  $103^{\circ}\text{F}$ .; she complained of headache and her neck was again stiff. Lumbar puncture the same evening showed the cells of the C.S.F. had risen from 66 to 2,500 in ten hours. The frequency of the intrathecal injections was increased, and her symptoms subsided. This was the first of seven relapses, most of which followed attempts to withhold intrathecal penicillin. No focal signs were ever detected except the right-sided deafness with nystagmus and the mild cauda equina syndrome. There was never any discharge from the ear and Mr. Macbeth, who saw the patient on several occasions, only found evidence of a transient otitis media and pan-sinusitis. He considered this part of her initial respiratory infection, and in no way responsible for the relapses and that there was therefore no indication for operation.

Unlike our other relapsing cases, in this case each relapse was milder than its predecessor and none was comparable in severity to the initial attack. The last relapse was treated with sulphamezathine only, as she had developed an intolerance to sulphadiazine (Total: sulphadiazine—136 grammes, sulphamezathine—141 grammes). Following this, recovery was permanent and she has now no residua from her long and trying illness except a moderate right-sided deafness of inner-ear type. The whole illness lasted thirteen weeks.

This case presents several points of interest:

(a) The C.S.F. at the onset of the illness was exceptionally purulent (25,000 cells/c.mm. and over 1,000 mg. of protein/c.c.). As might be expected under those conditions, a cerebrospinal block threatened to develop during the first twenty-four hours of her illness. This necessitated an intraventricular injection of penicillin. The following day the signs of incipient block had disappeared, and treatment could be continued by the lumbar route.

(b) A mild cauda equina syndrome developed during the first thirty-six hours of the illness and recovered after eight weeks. Both this and the nerve

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deafness were probably due to the deposition of fibrino-purulent material round the nerve roots, as there was no correlation between the appearance and disappearance of the symptoms, and the lumbar administration of penicillin

(c) During an illness lasting thirteen weeks the patient relapsed seven times. The earlier and more severe of these occurred while lumbar penicillin was already being given and were treated by increasing the frequency of the intrathecal injections. The later and milder relapses followed attempts to withhold intrathecal penicillin and were treated by giving a further course of injections, until the last which was successfully treated with sulphamezathine alone.

(d) Finally, this case illustrates the reversal in prognosis. Before the introduction of chemotherapy pneumococcal pneumonia complicated by septicaemia and meningitis was a lethal disease (Osler's Textbook of Medicine 1937). Now, with penicillin and sulphonamides, full recovery can be achieved.

*Precautions in use of penicillin intrathecally*—Treatment with intrathecal penicillin is not without its dangers. Of the four chief risks three are common to all cases of meningitis while the fourth is particularly apposite in those cases which follow infection of the ear or nose.

(1) The brand of penicillin must be suitable for intrathecal use. As soon as a non-irritating preparation has been secured it should be set aside for treatment of meningitis. The best at present available is crystalline penicillin 2 (Glaxo Ltd).

(2) Excessive dosage (40,000 u. or over at a single dose), especially when concentrated solutions are used, is capable of producing severe cerebral reactions, or, when given by lumbar puncture, damage to the cauda equina or gumming of the subarachnoid space. This last is particularly unfortunate as the most convenient route of access is then no longer available.

(3) There is a very definite risk of introducing secondary infection, especially when frequent relapses demand a large number of injections. For this reason the penicillin solution should be put in small quantities and each container only used once. A strict aseptic technique in preparation of solutions and in lumbar puncture is imperative.

(4) There is a danger in doing repeated lumbar taps on any patient with high intracranial pressure. This is probably negligible except when the meningitis is complicated by an abscess, when it is considerable. This combination of meningitis and abscess is particularly common in cases secondary to infection of the ears or nose.

Finally the closest observation and the best of nursing care are essential to success (Smith, Day and Welch, 1946). "You may hope to push the patient through, but to do so you must watch him hour by hour" (Watson, 1848).

## 2 THE DETECTION AND TREATMENT OF A COMPLICATING INTRACRANIAL ABSCESS

Intracranial abscess and leptomeningitis are both well known complications of otitis and sinusitis, and each has its own distinct symptomatology. Formerly we knew of cases where a cerebellar abscess was complicated by meningitis, and of others where a terminal meningitis and ventriculitis arose as a complication of abscess of the cerebral hemispheres. But since we have been treating

meningitis with penicillin we have met cases in which meningitis and intracranial abscess appear to develop together. The clinical picture may then be so dominated by the signs of meningitis that the abscess is not suspected until the patient, instead of making the expected response to intrathecal penicillin, becomes moribund from raised intracranial pressure.

CASE V.—R.I. 25905/44.

The patient, a child of 12, came under our care in the early days of penicillin therapy and before we were aware of this particular combination of abscess and meningitis. Thirteen days before she had been admitted to hospital elsewhere with an acute infection of the ethmoid and sphenoidal sinuses complicated by an orbital cellulitis. She was treated with sulphathiazole in doses of 6 grammes in twenty-four hours. The infection persisted and on several occasions she vomited and complained of headache. After twelve days the ethmoid sinuses were curetted and the same evening she developed signs of meningitis. Lumbar puncture yielded a turbid fluid in which streptococci were identified and the day after operation the child was transferred to Oxford.

On admission she was delirious and extremely ill, with marked meningeal signs. There were no focal signs except right-sided proptosis. Lumbar puncture was performed. The C.S.F. was purulent and the pressure well above 300 mm. of water. 25 c.c. were withdrawn and 10,000 u. penicillin in 10 c.c. injected. After the needle was withdrawn, C.S.F. leaked through the skin puncture for several minutes in spite of firm pressure. Following lumbar puncture she rapidly grew worse and four hours later she died. Autopsy revealed a large abscess occupying the right frontal pole.

We have now seen 8 such cases of simultaneous abscess and meningitis: 4 were otogenic and 4 followed pan-sinusitis. Of the latter 4, in 3 there was a history of severe, acute sinusitis, while in the fourth the intracranial infection followed a chronic sinusitis with osteitis of the skull. In 2 there were signs of orbital cellulitis. Of the otogenic cases, in one no adequate history could be obtained; in one there was a six weeks' history of earache, the tympanic membrane was very thick and scarred with a small anterior attic perforation and offensive purulent discharge; in the third there was a definite history of previous attacks of otitis; and in the fourth the abscess developed in a pre-existing brain fungus. It is thus possible that the abscess really predates the meningitis, although clinically they appear to develop simultaneously. The clinical detection of a complicating abscess may be extremely difficult especially as in none of our cases was any definite papilloedema detected.

In our experience the most important clue in diagnosis is the bacteriology of the infection. In our 26 cases of pneumococcal meningitis secondary to ear and nose infections, only 2 were complicated by an abscess. By contrast, among 9 cases of streptococcal meningitis an abscess was present in 5. An abscess was also found in our one case of otogenic staphylococcal meningitis. This same correlation between the bacteriology and abscess formation is seen in our cases of meningitis from other sources (fig. 2). The type of streptococcus was not determined in every case, but there is some indication that abscess is commonest in the anaerobic streptococcal infections (Cairns and Schiller, to be published). The abscess may be intracerebral or subdural or both, but wherever it is its detection is imperative since not only does the abscess itself

demand prompt surgical treatment but the meningitis must be treated by intraventricular penicillin instead of by the routine lumbar injections. Owing largely to the difficulties in diagnosis we have not yet succeeded in saving any of our otogenic cases of simultaneous meningitis and abscess. We have, however, been successful in two cases secondary to sinusitis.

CASE VI—R I *Illustrating the diagnostic problem of simultaneous meningitis and abscess*

A storekeeper of 47 was admitted to hospital as an emergency under the care of Mr Livingstone. For the past fifteen years he had suffered from intermittent attacks of mild right-sided earache associated with a thin watery

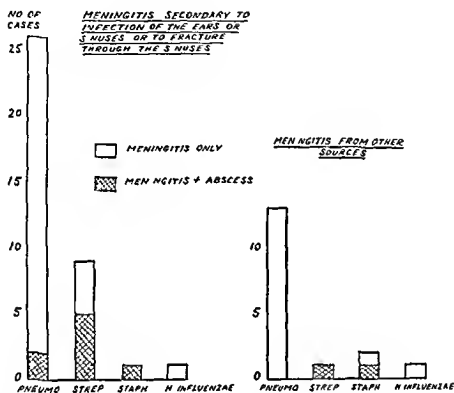


FIG 2

The incidence of a complicating intracranial abscess in the different bacteriological varieties of meningitis both in the cases forming the present series and in those of meningitis from other sources

discharge. Ten days before admission, the pain and otorrhoea returned, but later the discharge ceased and the pain became much worse. Twenty-four hours before admission he had a rigor and his temperature rose steeply.

On admission he was in considerable pain from his ear, his neck was a little stiff and his temperature just over  $100^{\circ}\text{F}$ . The right external auditory meatus was filled with thick pus. Lumbar puncture revealed a cloudy fluid under a pressure of 240 mm. of water. No organisms were seen on the films and cultures were sterile. Treatment with sulphadiazine was begun and a few hours later a right radical mastoidectomy was performed, and an extradural abscess opened. The middle fossa was widely exposed until healthy dura was found. The wound was closed with drainage.

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Following operation he steadily improved and nine days later began getting up. In the early hours of the tenth day the symptoms of meningitis returned with increased severity. The C.S.F. was found to be frankly purulent and to contain a number of streptococci. By 2.30 p.m. he was delirious and very ill with gross meningeal signs. No definite focal signs could be discovered on neurological examination. Treatment with intramuscular and intrathecal penicillin was begun but the lumbar C.S.F. was now so thick and the flow so sluggish that intraventricular injections were indicated. Accordingly bifrontal burrholes were made and the left lateral ventricle tapped. Here the pressure was found to be 500 mm. of water and about 30 c.c. of purulent fluid were withdrawn. The right ventricle was only found with difficulty and appeared collapsed. In the light of later experiences this finding should have been interpreted as indicative of an abscess but this was the first of our cases of simultaneous abscess and meningitis, nor were we aware at that time of the prevalence of abscess in streptococcal infections. An intraventricular injection of penicillin was therefore given and nothing further was done. The patient died quite suddenly about six hours after operation, and autopsy revealed, in addition to the leptomeningitis, a large subdural collection of pus overlying the right temporal lobe and in relation to the dura over the tegmen tympani.

In order to detect this difficult group of cases the procedure should be as follows :

As soon as meningitis is suspected in a patient who has well-marked signs of otitis or sinusitis he or his relatives should be questioned as to previous attacks and the patient then carefully examined for focal signs. A lumbar puncture is then cautiously performed, the initial pressure of the C.S.F. is measured and 4 to 5 c.c. slowly withdrawn. Cultures are set up and a Gram-stained film immediately examined. If pneumococci are recognized, and the C.S.F. is running freely, a lumbar injection of penicillin is given and the patient treated on the lines already described. If, however, streptococci are seen, an intracranial abscess should at once be suspected, and suspicion is greatly strengthened if the C.S.F. pressure is far in excess of 300 mm. of water or if focal signs have been elicited\*. A lumbar injection of penicillin may be given at the time of the diagnostic tap, but the presence of an abscess must then be confirmed or excluded by ventricular estimation or ventriculography, since penicillin makes ventriculography safe even in the presence of an active infection.

If no abscess is found the meningitis is treated in exactly the same way as pneumococcal meningitis. The sensitivity of the organism to penicillin should be assessed as some strains of streptococci are relatively resistant. Nevertheless, we have not yet needed to exceed our usual range of dosage.

If an abscess is found it must be dealt with surgically in order to prevent a fatal rise in intracranial pressure.

*Cerebral abscess.*—If the rise in pressure is due to the actual accumulation of pus, rather than to oedema, the abscess should be aspirated and penicillin is

\* Focal signs do not always indicate an abscess, but may be caused by cerebral thrombophlebitis. Thus in one of the cases in this series the patient developed a left hemiplegia and left homonymous hemianopia. Abscess was excluded by ventriculography. The whole of the intrathecal penicillin was given by lumbar injection, and recovery was complete.

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then instilled into the abscess cavity. Thorotrast may be injected at the same time, as it does not inactivate penicillin and facilitates subsequent management (Pennybacker, 1945). A more concentrated solution of penicillin is indicated for instillation into an abscess cavity than is advisable for intrathecal injections, and we use a solution of 10,000 u / c c as opposed to our standard intrathecal solution of 2,000 u / c c. The exact amount will to some extent depend on the size of the abscess cavity, but is usually 1 to 3 c c. If there is abundant pus, aspiration will be enough to control the rise in pressure, but if only a small quantity can be aspirated, the intracranial pressure must be controlled by ventricular taps or drainage. If this too fails the patient will require a decompression over the abscess, as unless the rise in pressure is relieved he will die but in the presence of meningitis wide opening of the dura should be avoided if possible since the raised intracranial pressure will produce great herniation with corresponding increase in destruction of the brain (Falconer and Russell 1944, Holbourn, 1944).

*Subdural abscess* — A subdural collection of pus is dealt with by the insertion of fine rubber catheters through suitably placed burrholes. Through these catheters, which are left open, pus is aspirated and penicillin instilled. The subdural space does not retain penicillin like the subarachnoid, and four to six-hourly injections are therefore needed. The number of burrholes required varies, but in one of our successful cases no fewer than five had to be made in order to ensure access to the whole of the subdural collection. When the limits of the subdural abscess have been defined, two further burrholes should be made through which the intraventricular penicillin can be given without passing the brain needle through the infected area.

The concomitant leptomeningitis is controlled by intraventricular injections of penicillin. These are begun when the diagnostic ventricular tap is performed and continued either by intermittent taps or if the ventricle is being drained by instillation through the catheter. The same scale and frequency of dosage is used as with lumbar injections but unless the intracranial pressure has been adequately lowered by aspiration of the abscess or other means no attempt must be made to treat the meningitis by the lumbar or cisternal route. These are not only useless but highly dangerous. The pressure of the abscess distorts the subarachnoid channels at the tentorial opening and elsewhere and may prevent the penicillin from reaching the ventricles or spreading upwards over the hemisphere (Cairns, Duthie, Lewin and Smith 1944). Moreover a lumbar or cisternal puncture carries a very real risk of producing a fatal pressure cone, nor is this risk lessened by an injection of penicillin.

In those cases of streptococcal meningitis where the patient's general condition is good when there are no focal signs or clinical evidence of an excessive rise in intracranial pressure, and where the C S F pressure is under 300 mm of water it is probably justifiable to institute treatment by the lumbar route provided the patient is closely watched for signs of rising intracranial pressure and provided also that full facilities exist for immediate ventricular puncture should the need arise. Even so an abscess may be missed. We have had 2 patients who fulfilled the above criteria and yet were later shown to have a small abscess. The danger signals are a progressive rise or fall in the pulse-rate, periodic respiration and an increase in stupor. The need

for constant observation cannot be exaggerated, and while the possibility of abscess exists these cases really demand the whole of the surgeon's time and attention.

Our experience with staphylococcal meningitis is very limited, but the fact that 2 out of our 3 cases have been complicated by abscess suggests that staphylococcal and streptococcal meningitis present similar problems.

## 3. TREATMENT OF THE PRIMARY FOCUS OF INFECTION

Since the time of Gowers (1888) immediate surgical drainage of the primary focus of infection has generally been considered axiomatic in the treatment of otogenic meningitis. Valuable as sulphonamides are in the treatment of meningitis, opinion is still divided as to whether or not they have lessened the need for immediate operation on the primary focus. Thus Watkyn-Thomas (1941) defined the principles of treatment as: (1) Elimination of the primary focus; (2) drainage of the subarachnoid space, (3) appropriate counter-medication.

Now that penicillin is available the place of operation in treatment should be re-assessed by otologists, and in this connection our experiences in conjunction with our otological colleagues may be of interest. Our series of 21 cases of otogenic meningitis has been analysed according to the incidence and time of operation, the history, the recovery rate and cause of death (Table II).

TABLE II

TWENTY-ONE CASES OF OTOGENIC MENINGITIS SHOWING THE TIME-RELATION OF OPERATION ON THE EAR TO THE COURSE OF THE ILLNESS, THE PREVIOUS HISTORY, THE RESULT AND THE CAUSE OF DEATH

Operation	No. of cases	Previous otitis	Re-covered	Died	Cause of Death
Mastoidectomy before meningitis ..	3	2	2	1	Abscess
Mastoidectomy at height of meningitis	3	1(?)	2	1	Heart failure and inhalation pneumonia
Myringotomy at height of meningitis	1	1	1	0	—
Mastoidectomy during convalescence	2	1	2	0	—
No operation	13	4	9	4	(i) Delay in chemotherapy, (ii and iii) abscess, (iv) acute cerebral oedema

One patient (Case II) had two operations. Previous otitis=a previous history of infection of the ear

In 3 cases mastoidectomy failed to prevent the development of meningitis several days later, though in one the operation was admittedly incomplete. It is possible that a prophylactic course of systemic penicillin, given either alone or with sulphonamides, over the period of operation might prevent the development of meningitis in such cases, since a protective action has been claimed for sulphonamides alone (Weinstein, 1942).

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Three patients had been operated upon at the height of the meningitis before they came under our care. In the 2 who recovered mastoidectomy preceded the institution of penicillin therapy by three days and three weeks respectively. In neither had it had any apparent effect on the meningitis which was already partially controlled by sulphonamides. In the fatal case mastoidectomy was performed immediately before penicillin therapy was begun. The patient had a stormy time during operation, he stopped breathing, and was with difficulty resuscitated. The following day he developed heart failure and died. A severe inhalation pneumonia was found at autopsy.

The single case in which an emergency myringotomy was done was one of fulminating pneumococcal meningitis.

## CASE VII—R I 23632/44 (Falconer *et al.*, 1946 Case III)

The patient, a schoolboy of 15, had an attack of right-sided otitis media in December 1943. This responded well to sulphonamides and he returned to school the following term. At 4 p.m. on April 14th, 1944, he had a recurrence of his earache and his temperature rose to 102.5°F. The ear was examined and though the tympanic membrane was reddened no indication for operation was found. He was given 2 grammes of sulphadiazine and thereafter received 1 gramme every four hours. Next morning at 4 a.m. he awoke complaining of headache and vomited. By 11.30 a.m. he was delirious and had considerable neck rigidity, the tympanic membrane was bulging. He was transferred to a nursing home where at 2.30 p.m. a myringotomy was performed and a fair quantity of pus released without any effect on his general condition. Since he was by now unable to swallow the sulphadiazine was continued by intramuscular injection.

By 5.30 p.m. he was desperately ill. There was pronounced head retraction, he was cyanosed, and his respirations which had risen to 40 per minute were interrupted by bursts of hyperpnoea when the rate would rise to 60 or even 70. He was mute and restless and any interference provoked paroxysms of violent but silent struggling. There was a right facial weakness of lower motor neurone type, but no other focal signs. Lumbar puncture yielded turbid fluid under a pressure of over 300 mm. of water and an examination of a smear of C.S.F. showed Gram positive diplococci. Pneumococcus Type 14 was grown on culture.

At 7 p.m., when he came under our care, he seemed *in extremis*. At this stage treatment was begun with intrathecal and intramuscular injections of penicillin. At 8 p.m. he was seen by Mr. Livingstone who advised against further operation on the ear.

During the next twenty-four hours there was little change in his general condition except that the rapid deterioration ceased. X-rays taken of his mastoids showed evidence of an acute mastoiditis on the right side. Twenty-four hours after treatment with penicillin was begun his temperature fell and thereafter his recovery was rapid and complete. During his illness he was again seen several times by Mr. Livingstone who was fully satisfied with the progress of the ear. When discharged from hospital, all the clinical and radiological evidence of infection had disappeared. When last seen, two years after the meningitis, there had been no recurrence of symptoms in the right ear.



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though a few weeks before this he had a mild attack of left-sided otitis media.

Thirteen patients had no operation. As soon as supplies of penicillin were adequate, all received from 120,000 to 320,000 u. daily by intramuscular injection, in addition to their intrathecal penicillin and oral sulphadiazine. This was continued until the active infection had subsided. Although there were four fatalities, in no case would the outcome have been altered by operation on the ear. One infant died a few hours after treatment was begun; here delay in instituting chemotherapy was the decisive factor. Two died from intracranial abscess and one from acute cerebral oedema. In the other 9 cases not only was recovery from the meningitis complete but there has been no return of the aural symptoms. Mr. Macbeth and Mr. Livingstone have seen most of these patients and, except in one (Case II), they have not advised operation. Only 2 of these 9 cases relapsed, and in both the intrathecal course of penicillin had been incomplete. The following case is an example of control of the primary focus without operation.

### CASE VIII.—R.I. 20891/44.

The patient, a schoolboy of 11, had always been a backward child. Three years earlier he had begun to suffer from recurrent attacks of right-sided otitis. From time to time he would complain of earache, then after a few days the ear would begin to discharge and the pain would cease. On May 14th, 1944, he developed a cold in the head and a purulent discharge from the right ear. Fourteen days later he complained of headache, grew drowsy and restless, and his parents noticed that his head was retracted. These symptoms all steadily increased and after five days he was admitted to hospital elsewhere. A lumbar puncture was performed and hæmolytic streptococci grown from the C.S.F. Treatment with sulphathiazole was begun and the following day he was transferred to Oxford.

Examination at that time showed an ill, wasted child with spina bifida, but no cauda equina symptoms. He was semiconscious and at times would scream with pain from the intensity of his headache. Head retraction and opisthotonus were so marked that he had considerable difficulty in swallowing. Upward movement of the eyes was limited but no other focal signs were found on neurological examination. There was no mastoid tenderness but thick offensive pus, from which a *Staphylococcus aureus* was cultured, was welling through a perforation in the right tympanic membrane. X-rays of the mastoids taken three days later showed sclerotic bone with a few small cells and an opaque antrum.

Treatment with sulphadiazine and intramuscular penicillin was begun immediately. In view of the possibility of a complicating brain abscess, the lateral ventricles were tapped through frontal burrholes. Both were found to be dilated which made the presence of an abscess unlikely. On culture, *Staphylococcus aureus* was grown from the ventricular and *B. hæmolytic streptococcus* from the lumbar fluids. Intrathecal penicillin was given by ventricular and lumbar injections and he made a slow but satisfactory recovery from his meningitis.

Mr. Macbeth saw this patient in acute phase of the illness and in view of our past experiences he thought it justifiable to await developments before advising

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operation This course was fully justified by subsequent events Six days later the perforation had healed and by the time the meningitis was fully controlled Mr Macbeth declared himself satisfied with the ear Follow up studies during the subsequent eighteen months showed recovery both from the meningitis and the otitis to be complete

Two patients were operated on during convalescence The first was the patient on whom complete mastoidectomy was performed some weeks after a relapse of the meningitis (Case II) The second was a girl of 14 who developed an acute right sided mastoiditis two months after she had apparently made a complete recovery from an attack of pneumococcal meningitis secondary to a mild right otitis media Mastoidectomy was performed elsewhere, and a pure culture of *Staphylococcus aureus* grown from the pus Though the relation between the original otitis media and the mastoiditis is therefore uncertain, operation early in convalescence would have prevented the second attack

Our successful cases in which no mastoidectomy was performed include examples of chronic otitis as well as of recurrent (Cases VII and VIII) and acute otitis In every case the ease with which the initial attack of meningitis was controlled was approximately the same Nor did the 6 patients who had had a mastoidectomy done before they came under our care respond better to treatment than those who had not In fact, in 1 fatal case the stress of anaesthesia and operation at the height of the meningitis probably prejudiced the patient's chance of recovery

Though we have thus no evidence that operation is of value in treatment of the acute phase of the meningitis, it sometimes has a place in the treatment of the relapsing case That the meninges can be reinfected from the primary focus is certain (Case II), but what is not known is how frequently this occurs Evidence is accumulating that reinfection from an intrathecal fibrino purulent collection (Case III) is the commoner mechanism During treatment of a case of meningitis whether otogenic or secondary to sinusitis, in which relapse follows relapse, the idea of an active primary extrathecal focus which is constantly reinfected the meninges is very difficult to resist Nevertheless in our experience, attempts to stop relapse by operative treatment of extradural sources of infection have been disappointing

Whether early operation is necessary in order to preserve hearing is not a matter for us to decide It is, however, interesting that while several of our patients have been slightly deaf on first recovering consciousness in only 2 has this been permanent In neither case was the meningitis otogenic and in both the deafness was of nerve type

Our experience with penicillin thus suggests that mastoidectomy need no longer be performed as an emergency in cases of otitic meningitis In this connection it is interesting that work done on experimental pneumococcal infections in animals shows that general anaesthesia (alcohol ether and avertin) inhibits the activity of the leucocytes and allows the organisms several hours in which to multiply unchecked (Pickrell 1938)

Once the meningitis has been cured, whether mastoidectomy is still required and whether this depends on the chronicity of the otitis are questions which must be answered by the otologist It is likely that the answer may be most

easily found from study of cases of otitis uncomplicated by meningitis. It is, however, clear from the observations made by our otological colleagues on cases in this series that, at least in the acute case, full recovery can be attained by systemic chemotherapy. In any case, the patient is dying not from the mastoiditis but from his meningitis. Prompt and adequate treatment of the meningitis must therefore take precedence over other therapeutic measures.

The treatment of acute sinusitis is less debatable. Adequate doses of penicillin can control the infection, even when this is complicated by frank osteitis of the skull. Even if this becomes reactivated after withdrawal of the systemic penicillin it can be dealt with at leisure after the meningitis is controlled.

When meningitis follows a fracture through the sinuses with tearing of the dura, the dural defect should be repaired as soon as the patient has recovered from his meningitis (Cairns, 1937). Similar treatment is not so often required for fracture of the petrous bone with tear of the overlying dura.

## RESULTS

In our 37 cases there have been 26 recoveries and 11 deaths (fig. 3). Up to the present time the prognosis has usually been considered best in cases

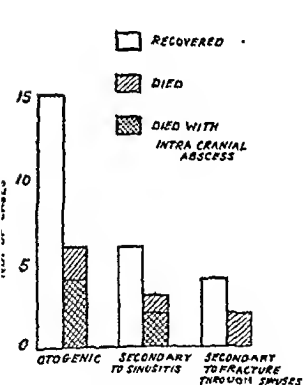


FIG. 3  
Classification of the results according to the mode of primary infection

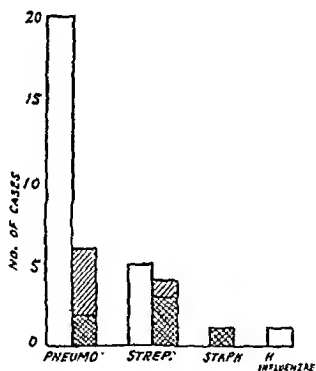


FIG. 4  
Bacteriological classification of results.

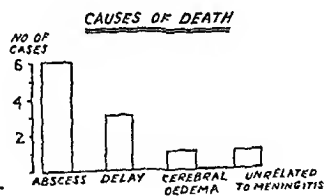


FIG. 5  
Table showing the causes of death.

of streptococcal and worst in cases of pneumococcal meningitis (Hutchison, 1942; Weinstein, 1942). Our results are very different. Out of 26 cases of pneumococcal meningitis, 20 recovered, while out of 9 cases of streptococcal meningitis, only 5 recovered (fig. 4). The reason for this difference in the prognosis is apparent when the causes of death are considered (fig. 5). A complicating abscess is the commonest cause of death, and the combination of abscess and meningitis is most common in streptococcal infections. In our 6 fatal cases of pneumococcal meningitis, in 2 only was death due to abscess formation. Three patients died from delay in instituting chemotherapy, and 1, a traumatic case, from fat embolism while recovering from his meningitis. Although we have not yet been fortunate enough to cure a patient in whom

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meningitis and abscess followed disease of the ear, our successes with cases secondary to sinusitis encourage us in the belief that no patient is too ill to recover with chemotherapy and suitable surgical intervention

## SUMMARY

Otogenic meningitis and meningitis secondary to infection of the nasal sinuses are considered together, since the problems of treatment are similar. Such cases fall into three main groups: (1) Those in which no organisms are recovered from the CSF, (2) those due to organisms which are relatively or totally resistant to penicillin, (3) those due to penicillin sensitive organisms.

A series of 37 cases (Table I), of which all but one fall into the third group is described. The predominating organisms were pneumococci and streptococci.

The basic treatment of purulent meningitis with penicillin is briefly recapitulated, the mechanism of relapse discussed, and the hazards associated with the administration of penicillin intrathecally are pointed out.

Eight cases have been encountered in which the meningitis was complicated by an intracranial abscess. Diagnosis of the abscess is difficult, since both abscess and meningitis appeared to develop simultaneously, but its detection and immediate treatment are imperative. This combination of abscess and meningitis is seen most often in streptococcal infections. In our total series, out of 38 cases of pneumococcal meningitis, only 2 were complicated by an abscess, while out of 10 streptococcal cases, a concomitant abscess was present in 6.

The treatment of the primary focus of infection is discussed since the use of systemic penicillin demands reassessment of the place of emergency mastoidectomy in the treatment of otogenic meningitis. In 21 otogenic cases with 15 recoveries only 2 patients had a mastoidectomy at the height of the meningitis, 13 patients had no operation on the ear, and of these 9 recovered completely from both the meningitis and the otitis. In none of the fatal cases could mastoidectomy have saved the patient's life, and in fact, operation with general anaesthesia may tip the scales against the patient when performed at the height of an attack of meningitis. Whether operation is still necessary once the meningitis has been controlled is a matter which must be decided by the otologist.

In the present series of cases the results with pneumococcal have been better than with streptococcal meningitis owing to the frequency with which the latter disease has been complicated by intracranial abscess.

Finally we would like to thank our colleagues Mr Macbeth and Mr. Livingstone, for allowing us to treat their cases and for the help they have given us with our own cases.

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MR. J. ERIC PATERSON: My observations are based on material treated in the Neurosurgical Unit at Killearn Hospital, near Glasgow. The Unit was established four years ago, and the material includes therefore cases treated before and after the advent of penicillin. It is selected material; most of the cases have been referred, either from an otologist or from a fever hospital, because progress was unsatisfactory, because some such complication as brain abscess was feared, or because it was felt that penicillin administration by some special route, such as into the ventricle, should be carried out.

In our penicillin cases we have had only 6 patients with uncomplicated otitic meningitis, that is, unassociated with other intracranial lesions such as brain abscess. Two of the 6 cases died, both had been sent in late.

*The sulphonamides in acute otitic meningitis.*—We give a course of sulphonamide in every case in very large doses. Until recently we used sulphamezathine since with this drug the risk of renal complications is very small; but since Kremer, Phillips and Stanier (1945) showed that it was most difficult to obtain with it an effective concentration in the cerebrospinal fluid we have used sulphadiazine, with which the concentration has been shown to reach 60 to 80 per cent. of the blood level. We have not yet experienced renal crystallization or agranulocytosis. We give a dose of 5 grammes and continue with 3 grammes four-hourly for the first twenty-four hours, followed by 2 grammes four-hourly for a week, when we allow one to two days to elapse without sulphonamide before beginning another such course, if this is thought advisable. When a sulphonamide is used alone—and it must not be forgotten that meningitis may result from a penicillin-resistant organism—the risk of sulphonamide poisoning must be balanced against the risk of a fatal ending in these grave cases. Following the lead of Mr. Norman Dott we have deliberately taken this risk. I know of one patient in whom, over a period of three weeks, a total of 318 grammes was administered, with final recovery; that is, an average dose of  $2\frac{1}{2}$  grammes every four hours throughout.

There were some excellent results in pre-penicillin days in streptococcal infections. One case of chronic otitis media which sustained a fracture through the petrous bone had acute meningitis with pus under the temporal fascia. Recovery was rapid after sulphonamide administration and a mastoid operation.

*Penicillin therapy.*—Our intrathecal doses have hitherto been generally not

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more than 40,000 units daily, but I shall increase the dosage in the light of what has been said, particularly now that the drug is available in an increasingly pure form. Penicillin reactions have occurred in a few of our cases: several patients complained of pain in the feet, which disappeared when the intrathecal injections were stopped. This we ascribed to an irritation of the cauda equina. Two cases ran a mild temperature, which fell at once to normal when the drug was withdrawn.

Intraventricular penicillin is given when there are signs of a cerebrospinal fluid block, but patients with obstructive hydrocephalus, sent to the neurosurgeon late, do badly; treatment must be prophylactic, early. For instance, a girl of 8 was admitted from a fever hospital. She had papilloedema, bilateral VIth and right VIIth nerve palsies. Ventriculograms showed a large hydrocephalus; the fourth ventricle was dilated, but the gas had failed to pass into the cisterna magna or forward along the base. She died sixteen days after admission; intrathecal, intraventricular and systemic penicillin was powerless to deal with the obstruction at the foramina of Luschka and Magendie.

But these foramina are small in size, and there are cases where, in the absence of signs of cerebrospinal fluid block, penicillin given intrathecally may be much less effective than when given by the ventricle. We have only very recently begun to estimate the cerebrospinal fluid bacteriostatic level, but the result is not available immediately, and it would seem wise to begin ventricular administration as soon as the sample of fluid has been taken, without waiting for the result. Here is a case which illustrates the importance of giving intraventricular penicillin in the apparent absence of obstruction. A girl of 7 was admitted a week after an acute head injury. There were a cerebrospinal fluid otorrhoea and a staphylococcal meningitis. Under systemic and intrathecal penicillin she continued to run a temperature for three weeks with varying, but often high, cerebrospinal fluid cell-count, while her general state deteriorated. Finally, when the count rose to 2,400, ventriculography was done. This disclosed ventricles which were normal in size, without any evidence of obstruction throughout the cerebrospinal fluid pathways. Intraventricular penicillin was started at once and the temperature fell to normal two days later; recovery was uneventful.

*Reaction to intraventricular penicillin*—Johnson and Earl Walker (1945) describe the case of a boy of 22 months who was given a dose of 50,000 units by this route. He became unconscious and so collapsed that his blood pressure could not be estimated. Three hours later he had a generalized convulsion, and this latter was repeated, without loss of consciousness, when he was given another injection three days later. In the case of the little girl just described there was likewise a considerable degree of collapse, without any convulsion; fortunately this is the only example we have had in our series. It is to be anticipated that such disturbances will become less frequent as the drug becomes available in purer form.

*Cisternal penicillin*—Little need be said about administration into the cisterna magna. Its place must be very limited indeed. Speaking as a neurosurgeon, I know I should much rather inject the drug into a ventricle than try to tap a cisterna magna in a child with pronounced opisthotonos. However, I have notes of one case of pneumococcal infection in which a spinal

block developed, and which made an excellent recovery with intracisternal penicillin.

*Systemic penicillin.*—Systemic administration is a most important part of the treatment of these cases; the difficulty is to know how long to continue the drug by this route; usually we play for safety and continue possibly longer than we need to. But we must not exaggerate the efficacy of systemic penicillin in acute meningitis or agree with Reese (1944) when he states that intrathecal penicillin is never necessary, since the drug is excreted into the cerebrospinal fluid in bacteriostatic concentration when the choroid plexuses are rendered more permeable by the disease. As the work of Professor Cairns and his associates has shown, in pneumococcal meningitis only traces of penicillin appear in the cerebrospinal fluid after the systemic injection of even very large doses.

I agree with Professor Cairns that operation on the infected ear should not be carried out in the acute phase of the meningeal infection before this is under control. In systemic penicillin we have a most potent weapon in the control of the spread of the infection from the primary focus to the meninges, and we must exploit it to the full. Operation under general anaesthesia may well turn the scale against recovery; and operation under local anaesthesia must be extremely difficult in a restless, delirious patient. But reinfection of the meninges may readily occur, and if operation is indicated it should be carried out as soon as acute infection has been overcome, while the patient is still on his initial course of systemic penicillin.

*Rigid asepsis in intrathecal and intraventricular administration is of extreme importance.*—In the past three years, I have treated three cases of staphylococcal meningitis following lumbar puncture. Two of these followed spinal anaesthesia, and there were two deaths in this small series.

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MR. R. G. MACBETH said that Dr. Honor Smith and Professor Cairns had asked him to comment on the otological aspect of their communication. It was obvious that with the coming of penicillin therapy otologists must accept a greatly changed outlook on the question of when or even whether they should open mastoids in the presence of otogenic meningitis. One thing which did emerge was that the mastoid operation need no longer be a matter of great urgency. One could safely delay doing a mastoid operation until the meningitis was under control, and the patient therefore more fit for operation.

In acute cases it seemed necessary only to do the simplest operation productive of drainage of the middle-ear cleft. Where the ear was discharging already, no operation might be needed; where there was no discharge, a myringotomy might suffice. Penicillin did not sterilize pus inside an abscess cavity, but it would aid the resolution of an inflammatory process within a draining middle-ear cleft. A patient who had an extradural abscess in the middle or posterior fossa was an exception to that rule, and it was probable

that one could get a hint about such a case from careful attention to clinical signs. For example, such a patient might complain of persistent pain and tenderness behind the ear in spite of adequate chemotherapy, and continue to have otorrhœa and cells in the cerebrospinal fluid.

Relapsing cases of meningitis seemed to be commoner with nasal sinus infections than with mastoiditis, as one would expect from a consideration of the connections between the nasal sinuses and the subarachnoid space.

It seemed likely that operation would be called for in almost every case of meningitis due to chronic otitis. It was difficult to imagine that a sufficiently high concentration of penicillin could be delivered to deal with the primary focus in chronic bony disease.

MR. T. B. LAYTON said that no distinction had been made in the paper presented by Dr. Honor Smith between chronic ear disease and acute inflammations of the middle-ear cleft. In every paper dealing with an otological subject that distinction must be made. The two diseases were as distinct clinically, bacteriologically, and therefore pathologically, and in their response to treatment, as were acute peritonitis and tuberculous peritonitis.

He disagreed with Mr. Paterson that it might become unnecessary to operate on the acute ear, but that operation had still to be done on the chronic ear. He had made the planned experiment of refraining from operating in meningitis of an acute ear because he thought that a condition of the heart was the dominating lesion which would forbid a general anæsthetic to be given. The patient came out of the meningitis but relapsed. He then had operated, but the patient died. He would find it a very grave responsibility to refrain from removing that factory of organisms which was down against the dura mater. There was a distinct difference in disease of the ear and the sinuses. One was a disease of bone, contiguous with which was the periosteum—the dura mater, and therefore the spread from one to the other was easy and rapid; the other was an inflammation of a mucous membrane separated from the cranial cavity by two layers of periosteum and an intervening piece of bone, and all one could do was to drain that cavity, if one knew exactly from which of the half dozen or so channels it was spreading through to the meninges.

MR. E. MUSGRAVE WOODMAN said that those working so extensively on penicillin were to be congratulated on the change that had taken place in the prognosis of pneumococcal meningitis. He had always been taught that pneumococcal meningitis was an incurable disease.

Why was it that penicillin seemed so impotent to control a migrating streptococcal abscess in the brain?

As to whether they should operate on an acute mastoid which was accompanied by meningitis or brain abscess, they had all been taught that the primary focus should be removed when consequential complications arose. But these patients were very ill, their margin of safety was low, and a little thing would tip them over the border. In the best interests of the patient it might be that a simple drainage without eradication should be carried out.

MR. C. P. WILSON said that probably those cases which developed symptoms associated with a cerebral abscess were more likely to go to a neurosurgical unit than to an otologist. In his 8 cases of otitic meningitis there had been



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only one death, and that was in a pneumococcal case. 3 cases had grown a hæmolytic streptococcus, and all had recovered.

*Intrathecal dosage.*—He had discussed this with Professor McIntosh, pathologist at the Middlesex Hospital. Originally these cases were given 2,000 units per c.c. intrathecally according to the amount of cerebrospinal fluid removed, but lately they had been using as much as 50,000 units in otitic and non-otitic cases. He queried this amount with Professor McIntosh, because he felt it was much more likely to produce a local reaction with fibrinous exudate, but Professor McIntosh's opinion was that these cases often had fibrinous exudate without penicillin, and he (Professor McIntosh) thought that the amount of exudate was not greater with penicillin, but it so happened that the patients lived instead of died. Apart from that, any complications which arose were not serious. In this series they had had only two complications: One patient had a paralysis of the median nerve which was now recovering, and another had symptoms of *petit mal*. Thus the disadvantage of using very large doses of penicillin intrathecally did not seem to have been particularly borne out in Professor McIntosh's cases at Stoke.

MR. L. GRAHAM BROWN said that four months ago he had a case of acute mastoiditis, a flare-up on a chronic infection. He carried out a complete mastoidectomy. The patient did very well for three weeks and then developed a facial palsy. He reopened the wound and cleaned up the infection still present. Since the pyrexia and headache continued he carried out a cerebrospinal examination and found about 800 cells present. He called in a neurologist, who, however, could not locate anything intracranially. The patient was put upon sulphonamide treatment and penicillin systemically. He did very well, the wound healed up completely, the temperature fell, and the patient left the hospital. A month later, however, he returned with further symptoms, and he referred him to the neurologist. He (Mr. Graham Brown) suspected that the patient was suffering from a sphenoidal abscess, but his hand was stayed by the neurologist. He was ready to operate, but before any further information could be elicited the patient died. At post-mortem a sphenoidal abscess was found.

Interesting from the point of view of the relationship between the otologist and the neurosurgeon and neurologist. It was obvious that the otologist had a little difficulty in carrying out completely all those difficult tests and treatments which the neurosurgeon was now making his own. He desired to ask Professor Cairns if he did not agree that, in those cases where brain abscess or an intracranial complication was suspected accompanying meningitis, the neurosurgeon should take charge. He was one of those otologists who thought that these cases were really getting beyond their range of full responsibility.

MR. TERENCE CAWTHORNE said that a contribution from outside was always welcome at that Section particularly when it carried with it the experience of the Neurosurgical Department at Oxford. Penicillin had quite clearly altered in some respects their views of otogenic meningitis. He desired to ask whether there was any likelihood of systemic penicillin being able to be a substitute for intrathecal medication. These constant lumbar punctures

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were a source of trouble and possibly a danger. He had seen two cases of meningitis secondary to lumbar puncture, both in cases in which spinal anaesthesia was carried out, and the organism in each case was *B. pyocyaneus*.

Mr Layton's very forcible exposition of the importance of differentiating between acute and chronic otitis media would command general agreement. They were two quite different diseases when it came to the management of an otogenic meningitis. On the question of draining a primary focus it might be asked, what *was* a primary focus? Meningitis following rapidly upon an otitis media was a mucous membrane disease not a bone disease, and the infecting focus could not be eradicated by carrying out wide surgical excision of bone. This only made it easier for infection to spread even further. The meningitis which followed within hours or days upon an otitis media should be dealt with conservatively.

Meningitis following upon a long standing otitis media was a different matter. He had in the past said that he thought such cases should be operated on without delay, but he now felt that it was wiser to give chemotherapy and the antibiotics a day or two's start before operation. He had no doubt that in cases of intracranial complications of chronic suppurative otitis media the best way of getting a good result was by intimate co operation between the otologist, the neurologist and the neurosurgeon.

MR F W WATKYN-THOMAS said that to control meningitis by any chemotherapeutic method, sulphonamide or penicillin, they must have an agent which would penetrate the perivascular sheath, pass along the vessels, and percolate the brain substance. The sulphonamides passed the choroid plexus entered the ventricles and passed, by the perivascular spaces through the brain. Was there evidence that penicillin, unless administered by the intraventricular route, would do that? To what extent would intrathecal penicillin do anything except pass over the outer surfaces and eventually be absorbed? Would it actually enter the brain substance? He knew that theoretically it was possible to get a reverse current of the cerebrospinal fluid, but was there any evidence that that occurred in penicillin administration? He was deeply impressed, but not quite convinced by Dr Honor Smith's paper, and he did not think that he was going to abandon the removal of the focus when there was one. Later on he might be converted.

MR H V FORSTER said that only a few days ago he had been asked to examine a man who had recovered from acute purulent meningitis associated with a history of inflammation in one ear. Intrathecal and systemic penicillin had been successfully given.

At his, Mr Forster's examination, the middle ear disturbance was found to have subsided and the drumhead to be intact.

In earlier days before sulpha and penicillin therapy one expected to see few cases recover from meningitis, complicating an acute primary otitis media.

In acute inflammation of the middle ear cleft, he had always felt that early drainage through its bony walls should be withheld and would like to support Mr Cawthorne's views on the pathology of this type of infection.

In chronic otitis media with an exacerbation, complicated by meningitis of markedly purulent type it had not been unusual in earlier days to see recovery after eradication of the primary focus of disease, assisted by lumbar puncture.

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Perhaps a certain degree of immunity had been developed through the years of chronic infection. In such cases, the possibility of a complicating brain abscess would confront the otologist who need not fear to explore for it with the serum needle and a syringe to provide suction to draw off the pus. He had great confidence that if the abscess cavity were entered by the needle, pus would not refuse to be drawn into the barrel of the syringe. He did not think that to explore through the roof of the operation cavity in this way gave any serious risk of infecting healthy brain tissue and the resulting instrumental trauma was not greater than that following the puncture in ventriculography.

Fatal cases of otitic brain abscess followed to the post-mortem room rarely showed an undrained loculus but a condition of spreading encephalitis.

Was there any evidence to show that penicillin was able to control the advance of the encephalitis?

THE PRESIDENT said that this interesting discussion could be summed up by saying that certainly penicillin did hold out the hope of helping cases which were hopeless in the past. It had also demonstrated the need for co-operation between the otologist and the neurosurgical units, and they were very grateful to Oxford for setting such an outstanding example of this.

PROFESSOR HUGH CAIRNS, who replied on the Discussion, said this subject had reached a stage at which the pathology of the primary focus had become of urgent clinical interest. The use of modern antibiotics in any field of pathology raised individual problems peculiar to that field, and the question of the infection of the mastoid and petrous bone was no exception to this rule. Neurosurgeons and other people working at Oxford had been drawn closer to the otologist over the use of penicillin than they had ever been before. He thought particularly of the cases of pneumococcal meningitis where relapse occurred. The patient got cured of one attack of pneumococcal meningitis and then got another, and this sequence might go on for months, and they found themselves badgering their otological colleagues to come and tell them whether there was a primary focus in the ear which was still active and whether it ought to be operated on, rather hoping that they would say "Yes". That was just one example of the type of thing with which they were now confronted.

*The dosage of intrathecal penicillin.*—They were very much against large doses; the standard dosage intrathecally should be about ten thousand units in one dose. It might be given twice a day in the very acute phase of the meningitis, but for most of the time it was sufficient to give it once a day. Excessive doses could cause trouble—fits, retention of urine, and other symptoms of damage to the cauda equina. Furthermore, all the available evidence went to show that excessive dosage was unnecessary. With the dosage recommended a concentration of penicillin in the cerebrospinal fluid would be obtained which was more than ample to destroy any of the ordinary pathogenic bacteria like pneumococci or streptococci.

Intrathecal treatment must be systematic, and the least time for intrathecal treatment in a proved case of pathogenic meningitis was five days. Often it was desirable to go on for rather longer.

What penicillin could do prophylactically, both for infection at the mastoid and infection at the brain, had yet to be proved. Mr. Watkyn-Thomas put a

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fundamental point when he asked whether the penicillin could diffuse into the brain from the capillaries. The answer was that nobody knew, and it was an extremely difficult problem to work at experimentally. It was known that, given systemically, the penicillin would not pass in any appreciable amount into the theca. It was also known that patients who were given penicillin systemically in adequate doses would still have relapses of meningitis. Therefore in answer to Mr Cawthorne's question, he did not think there was any likelihood, with the present compounds, that systemic treatment would replace intrathecal treatment.

If Mr Layton would read the opening paper he would find that they had in fact distinguished between the acute and the chronic cases. A chronic focus, where there was a collection of pus or sequestra, ought to be dealt with surgically. However he was not clear from what had been said whether Mr Layton would hold his hand in any case or whether he would go ahead and operate on all of them acute and chronic, as he did in the old days. As far as osteomyelitis of the long bones was concerned surgeons had changed their views very considerably since the advent of penicillin.

Patients who got an attack of pneumococcal meningitis did not seem to become more immune at any rate not for a long time. Relapses, of which there might be eight or nine in one case, were just as severe as the initial attack. If each attack of meningitis were treated as patiently and energetically as the first and the surgeon in charge did not lose heart or allow the nurses to lose heart, success would be achieved and the patient would in the end cease to relapse.

There was a great field here for the otologist to work out precisely the degree to which penicillin could help him in the treatment of mastoid infection and also in its prevention in cases of otitis media.

## Abstracts

ulcerations not associated with perichondritis of the arytenoid cartilages were definitely relieved of pain ; they were able to eat, gained weight and generally became improved.

The writer feels that the tuberculous ulcer was not the cause of the pain but the secondary infection of this ulcer by pyogenic organisms. The sulphanilamide eliminates the pyogenic organisms and the pain immediately disappears.

ANGUS A. CAMPBELL.

*Der Kragenschnitt bei den Fachärztlichen Operationen am Hals.* E. LUSCHER.  
*Acta-Otolaryngologica*, March 1st-June 30th, 1946, xxxiv, 2-3.

The author reviews the literature of laryngeal operations and quotes his personal cases. He recommends a transverse incision in the neck for thyrotomy and laryngo-fissure.

G. H. BATEMAN.

### NOSE

*On Rhinological Methods of Operating Large Dental Cysts in the Upper Jaw.*  
HARRY BJORK. *Acta Otolaryngologica*, March 1st-June 30th, 1946, xxxiv, fasc. 2-3.

The author recommends a rhinological approach to the surgery of these cysts. Central cysts should be drained into the floor of the nose and lateral cysts should be treated by a Caldwell-Luc incision, removal of the cyst lining, removal of the common wall between the cyst and the antrum and drainage of the antrum into the nose through the inferior meatus. Dental treatment should be completed before the cyst is treated. He considers that the method of Partsch, removal of the external wall of the cyst and packing the cavity from the mouth, is tedious and out dated. The article is well illustrated.

G. H. BATEMAN.

### ŒSOPHAGUS

*External Operations for Removing Foreign Bodies from the Œsophagus.*  
HARRY BJORK. *Acta-Otolaryngologica*, March 1st-June 30th, 1946, xxxiv, 2-3.

The author reviews the literature of œsophagotomy. He reports four personal cases of œsophagotomy.

He concludes: that external operation is seldom necessary when good endoscopic equipment is available. That external operations should be performed without delay if endoscopic removal fails, or if signs of perforation are present.

That cervical œsophagotomy combined with manual removal or endoscopic removal is indicated if the foreign body is at or above the bifurcation of the trachea.

That gastrostomy combined with manual or endoscopic removal is indicated if the foreign body is below the bifurcation.

That bilateral drainage operation is indicated when extensive inflammation in the neck is present.

That trans-thoracic œsophagotomy is not necessary and carries a much higher mortality than cervical œsophagotomy or gastrostomy.

G. H. BATEMAN.

# Miscellaneous

## MISCELLANEOUS

*Penicillin Therapy in the Practice of Otolaryngology* Lieutenant Colonel  
GILBERT C STRUBLE *Arch Otolaryng*, 1945, **xvii**, 5, 327-338

The writer and his associates outline their conclusions as follows

*Sinusitis*—Penicillin administered by intravenous and intramuscular injection has a favourable effect if the sinusitis is in an early stage and acute empyema has not already developed. It has usually shown no more promise than adequate and carefully followed up treatment with the sulfonamide compounds. In subacute and chronic empyema of the ethmoid and sphenoid sinuses, local penicillin shows great promise.

*Acute Otitis Media and Mastoiditis*—If penicillin is given early, the infection may be aborted. It must be given in adequate doses and over a sufficiently long period to prevent development of penicillin resistant strains of bacteria and relapses. If given late, it may mask the infection and symptoms. If the surgical indications for drainage are still present, myringotomy and mastoidectomy are resorted to. In cases of mastoiditis or petrositis, one may not rely on penicillin pre-operatively or post-operatively to prevent or control extension of the infection to the meninges and brain, because it does not reach the spinal fluid in appreciable amounts. If after mastoidectomy, any intracranial extension is feared, give sulfonamide drugs in addition to penicillin. In most cases of acute infection of the middle ear or mastoid, sulfonamide drugs given early have been found to be as effective as penicillin. Late in the disease, either of these agents may mask symptoms.

Local post operative application of penicillin receives favourable comment.

In *Chronic Otitis Media and Mastoiditis*, both systemic and local use of penicillin are reported on unfavourably.

No statistics are given, but illustrative cases are recorded.

R B LUMSDEN



# The Journal of Laryngology and Otology

(Founded in 1887 by MORELL MACKENZIE and NORRIS WOLFENDEN)

*August 1946*

## OTO-RHINOLOGICAL PROBLEMS OF OFFENSIVE DIVING

By Surgeon Commander S GAY FRENCH R N (Retd )

### Author's Note

THE following article is, regrettably, over-full with Naval technicalities, but the avoidance of these has been found impossible without becoming verbose and boring

It may not be out of place to remind those who have not been connected with hydrostatic problems that water is a remarkably heavy substance, one cubic foot of water weighing 64 lbs, and every thirty-three feet of depth subjecting the diver to one atmosphere plus of pressure

D S E refers, of course, to the Davis Submarine Escape (Apparatus or Chamber)

R of D and R of A have been used for Rates of Descent or Ascent

By the beginning of 1943, offensive diving was sufficiently advanced to be classed as a war weapon of some importance. The physiologists were gaining control of such problems as oxygen poisoning, but, in February, Surgeon Commander C L G Pratt, M Sc, R N V R, reported from H M S "Dolphin", his headquarters, that he was not satisfied in regard to aural and sinus problems and required the services of an otologist. The writer was accordingly, appointed to Special Service, and given facilities of the whole team, which included Surgeon Commander Pratt and his team, working at "Dolphin", Dr G L Brown (the secretary of the R N P R C), and his team working at the National Institute for Medical Research, the Admiralty Experimental



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Diving Unit with Professor J. B. S. Haldane and Surgeon Lieutenant-Commander Donald, and the whole-hearted co-operation of the executive branch (diving) with their experience and equipment.

Apart from the highly individual divers, such as the "Frogmen" who rarely went to any depth, three types of midget submarine were then being used.

The Welman, a one-man submarine, presented no problems from the writer's aspect, as it was, in fact, a miniature submarine, in which the subject remained at atmospheric pressure.

In the other two types, the aural and sinus problems were similiar, since each used a free diving suit, with oxygen bottles, named after Commander Sladen, R.N. (i/c Development Human Torpedoes). These two types were the X-Craft and the Human Torpedo. The latter (known by the code name of Chariot) where a crew of two in Sladen diving suits rode a torpedo, as one would a horse, was controlled, not only by trimming, as in a submarine, but also by a control column, similar to that of an aircraft, actuating the hydroplanes and rudders, with a four speed motor control, (maximum speed being 2.5 knots submerged) and an underwater dashboard, containing clock, depth-gauge, compass, battery meter, etc.

The suit requires some description, since its design was closely connected with the aural problems.

It was constructed of rubberized fabric, entry being effected through the body of the suit, feet first, then arms, and finally the top with head-piece attached was pulled over the head, leaving the body entrance in the form of a funnel, which was closed and sealed. The headpiece was loosely moulded to the shape of the head, but contained a rubber rim, fitting tightly round the head in the sagittal plane, so that, from this seal forward to the visor, virtually a gastight compartment was formed, containing the face, ears, in fact, the anterior half of the skull.

The vizor could be raised and was secured, underwater, by butterfly nuts, and below this was incorporated a rubber mouthpiece, very similar to that used in the D.S.E. Apparatus. Outside the suit, on a harness were the oxygen bag, with protosorb container incorporated, with two oxygen bottles, slung in the small of the back, the by-pass and the reducer valve coming readily to hand in the right loin. The bag, *via* a two way air-oxygen valve, was connected to the outboard end of the mouthpiece after the suit and harness had been donned, and it was necessary to wear a nose-clip, of standard pattern, to avoid a dangerous  $\text{CO}_2$  in the dead space between the face and the vizor. Part of the discomfort then being experienced was due to this tight face seal, and with the necessity of keeping the mouthpiece in place (the rubber flange with the teeth) practically splinted the

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Accepted methods of clearing the ears could now not be used. Trussed up like this, it was impossible to get at the nose, in order to perform Valsalva, and yawning and jaw movements were most difficult.

The diver was, therefore, thrown back on Toynbee's manœuvre (which, in certain subjects, does not work), or of having to perfect that difficult procedure, used by the experienced diver, which appears to be a dissociated contracture of the *tensores palati*, *salpingo-pharyngeus* and other tubal muscles. Few people can master the latter without months of practice and, at this period of the war, the time was not available, for it was desired to turn out operational crews in a matter of months. Due to these, and other factors which will be discussed later, the situation early in 1943 was that not less than 30 per cent of crews training were, at any one time, unable to dive, for days or weeks, due to having sustained some degree of pressure damage to the ears and, less frequently, to the sinuses.

Matters were not improved by the choice of area for intermediate training, made necessary for secrecy purposes, and in order to accustom crews to Norwegian conditions, this was the West Coast of Scotland, where diving went on in very cold water in a Scottish winter! It is not surprising, therefore, that the incidence of nasopharyngeal infection, either acute or chronic, was high, thereby making the problem of the ear clearing even more difficult.

This, then, was the problem presented, and a reconnaissance trip was made to H M S "Titania" where the divers, having completed their preliminary training in the Sladen suit in Horsea Lake, Portsmouth, were being taught to ride the Chariots.

From the start there were two big imponderables. Firstly not enough was known about the pathology of otitic barotrauma. Secondly, nothing was known about the dive rates of the Chariot, and, therefore, the pressure increase per unit period of time to which the divers' ears were being subjected. It was felt that, once some sort of danger limit could be produced for dive rate, a large part of the problem, from the operational point of view, would have been solved.

Everybody in the ship was eager to help with any required information, but it was soon clear that no one, divers or technical officers, had the required information to give.

While remarkably stable laterally, the Chariot was ultra-sensitive on its fore and aft trim, so much so that a small error in trim caused the machine to become uncontrollable on the hydroplanes, which worked through a total angle of 90°.

When this occurred, the Chariot would go into an uncontrollable crash-dive of increasing steepness and divers were unanimous that, when this occurred, the machine ended up in a vertical dive, standing on its nose.

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It is not surprising, therefore, that the unfortunate jockeys were far too busy trying to save themselves and the machine to make timed observations on the depth gauge (which, incidentally, was of the Borden type and therefore subject to lag.)

On return to town, therefore, work was started on a suitable recorder. After discarding such complicated ideas as underwater cine-cameras, a simple machine, which met requirements, was evolved. This was so satisfactory and sturdy that the following description is included in this article (1).

"Thanks to a suggestion made by Commander E. Terry, R.N., I was able to evolve, during the week prior to my visit to H.M.S. 'Titania', a modification of the standard Depth and Roll Recorder (Barr and Stroud, Mark III) which met these requirements. In the following reports all records were made with instrument No. 1940, specially modified.

"It is considered that such an instrument, or further modifications of it, will be of great use in the future in the investigation of underwater problems of this kind, and it is proposed to describe the machine in some detail.

"It has the following advantages:

1. It is very portable and almost completely foolproof.
2. It can be attached to anything which goes underwater, from a diver to a submarine, used in wet or dry chambers, D.S.E. chambers, etc. I have used it myself, in lieu of my weights, for experimental dives, thereby allowing complete concentration on the experiment in hand, and examination of the record at leisure afterwards.
3. It can be switched on and off under water.

"It has the present disadvantage (for some types of investigation) that it does not run long enough. This could be overcome by fitting different type drums and a stronger spring, or by having two or more machines to be run in series. The degree of accuracy can be seen from the records, and is considered to be sufficient for the proposed investigations.

"The Depth and Roll Recorder consists of a pressure recorder, actuating a brass stylus, through a system of levers, which records on a drum of chemical paper. The drum is driven by clockwork, and is fitted with a gear system, allowing of three speeds, and a governor, with screw adjustment. The pressure recorder is of the plunger type, acting against a spring, three strengths of which are available (35 ft., 50 ft., and 100 ft. springs). The roll recorder is a pendulum weight with attached stylus writing on the same drum. This is removed in toto in the modified instrument. This removal allows of each spring recording some 16 per cent. over its stated depth—i.e. the 50 ft. spring will record to 58 ft., but it is perfectly safe to exceed this depth, as extra pressure is taken up on the framework of the instrument. The whole is enclosed in a watertight case, with starting lever outside, and is of sturdy construction.

"Some work is needed on the governor to get the error in drum speed as small as possible. In the machine used, various governor-springs were tried, until the governor ran true. These springs are supposed to be of a standard

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pattern, but appear to vary in practice, and an additional recorder which was sent for from Greenock during my stay in H M S 'Titania' was so inaccurate, as regards the governor, that it was never used, and was still the subject of experimental work by the Torpedo Gunner's Mate when I left

"All that is left is to calibrate the drum speed against a stop watch with the aid of the governor-regulating screw. In the machine used (average of ten one-minute runs) the times were as follows

<i>Fast Speed</i>	48.2 cms /minute	Error $\pm$	3%
<i>Medium Speed</i>	12 cms /minute	Error $\pm$	1%
<i>Slow Speed</i>	3.8 cms /minute	Error $\pm$	0.3%

"In practice the medium speed was used, with one exception, when the slow speed was used to get a running time of over 30 minutes. The fast speed uses up the paper too quickly, and the slow speed cramps up the graph too much. The length of a roll of paper is 127 cms

"The 50 ft spring was used throughout, with one exception during the estimation of the vertical sinking component of the Chariot, when the 100 ft spring was used

"The depth is measured from the record with a protractor and, in view of the slightly different density of the water in the Loch, the instrument was recalibrated for depth on arrival in H M S 'Titania', being lowered 17.5 ft stages on a marked shot line, timed by a stop watch

"It is considered, furthermore, that this instrument would be of considerable use for training purposes, during the early parts of the curriculum of Chariot driving. In interrogating men who have inadvertently done a crash dive, I have been struck by the extraordinary discrepancies in the accounts due, of course, to the drivers being preoccupied with getting the machine under control. If fitted as standard to all training Chariots in the event of a badly managed dive the record could be examined and analysed at leisure, as is done in the Link trainer

"In all the records appended to the reports the time scale is *Two millimetres to one second*"

From the above it will be seen that future underwater otologists have a virtually foolproof method of dive analysis in any experiment they may care to undertake

The recorder was taken North to "Titania" and there after recalibration, was lashed to a Chariot with all tanks flooded, which was allowed to sink on the end of a line, thereby establishing the vertical sinking component. Maximum underwater speed was known and Figs 1 and 1a are parallelograms of force, which show that the pressure increase of a crash dive is, indeed, formidable, being comparable to an aircraft descending from 35,000 ft to ground level in 4.2 seconds'

Indeed it is doubtful if the most experienced diver, adept in the art of clearing his ears, could withstand such a rate, even if his clearing drill was not hampered by the obstacles imposed by the Sladen suit

Here, then, was another limiting factor. In theory, were the

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Eustachian tube to be rigid with a permanently patent lumen, vast rates of descent, such as the above, would be possible and would be limited only by the bore of the tube.

In practice the Eustachian tube is only a potential tube, being flat and occluded in cross section and only patent under the influence of

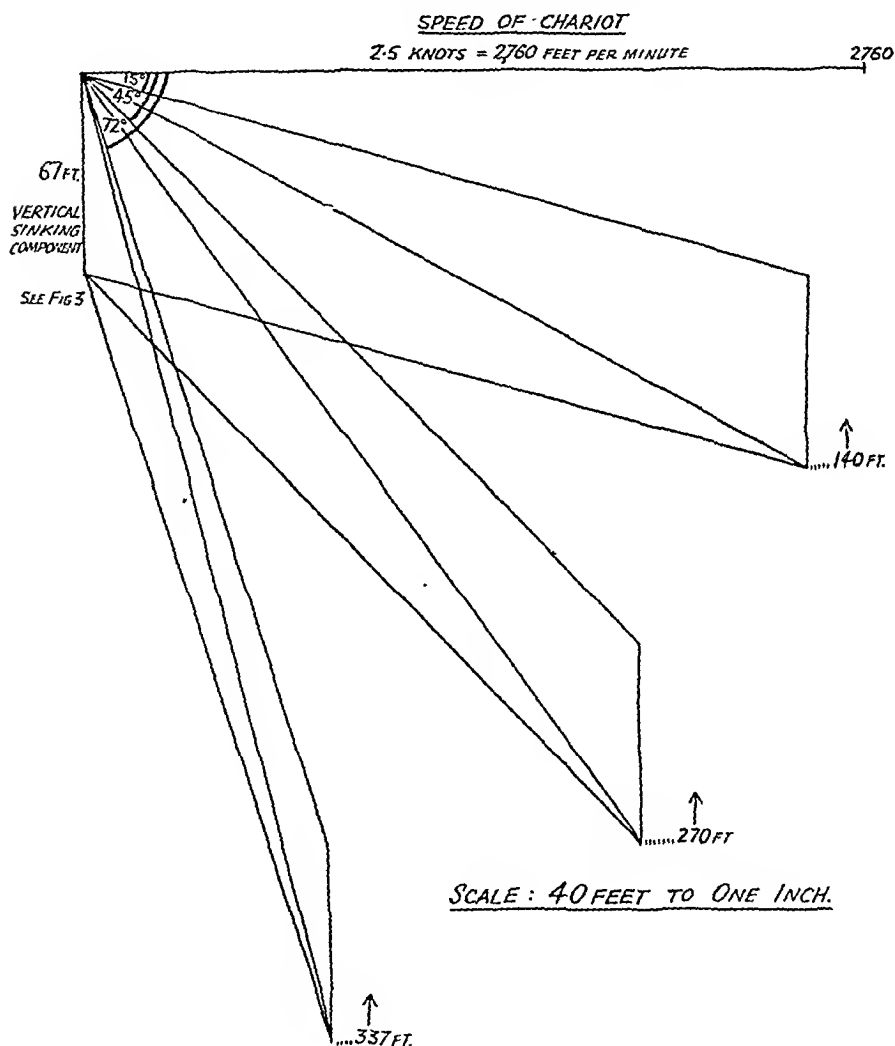


FIG. 1.

Computation of dive-rate of Chariot under the most adverse circumstances, i.e. fully flooded. Diagonals show actual distance travelled by Chariot through water—depth measured vertically in feet.

Speed 2.5 knots		
at 15°	$\left\{ \begin{array}{l} 140 \text{ ft./min.} \\ 2.33 \text{ ft./sec.} \end{array} \right.$	at 45°
		$\left\{ \begin{array}{l} 270 \text{ ft./min.} \\ 4.5 \text{ ft./sec.} \end{array} \right.$
		at 72°
		$\left\{ \begin{array}{l} 337 \text{ ft./min.} \\ 5.6 \text{ ft./sec.} \end{array} \right.$

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various tubo-palatal muscles (tensor palati, salpingo-pharyngeus, to some extent the upper part of the constrictor group)

When these contract (as they do in a percentage of subjects during the act of swallowing) or when the tube is pulled open by yawning or movements of the mandible, then only can air enter the middle-ear cleft and equalize pressure differences, unless positive pressure is employed, as in the practice of Valsalva. Any abnormality of the

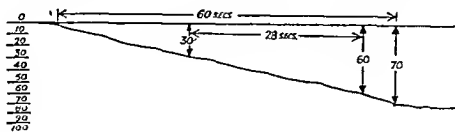


FIG 1a

Chariot fully flooded and sinking horizontal

structures concerned, such as infection, acute or chronic, mitigates against ease of clearing, and it was therefore decided that, in view of the mechanical difficulties already referred to, the oto-rhinological standards for acceptance would have to be tightened up

This could easily be done, as there was no lack of volunteers for this type of service, though both officers and ratings were simply asked to volunteer for a "hazardous operation", without knowing what this was

At this particular time a fresh class was just starting the preliminary training, about which a word must be said

A week of instruction in the D S E A Tank was followed by a course in the standard helmet suit, after which candidates were introduced to some weeks of diving in the Sladen suit in Horsea Lake. During this they also did synthetic night diving, and ended this part of the course with a depth endurance test. By the end of a couple of months or so, the diving instructors had a fairly good idea of who was likely to make a good offensive diver, and it was only after this that the class went up to Scotland, where they saw their machines for the first time and were taught how to ride them

This particular class had just started, being in the middle of their helmet course, and it was decided that the writer should accompany them throughout their training as their "tame otologist", diving with them where the occasion warranted

The first step was a thorough oto-rhino-laryngological examination, particular attention being paid to the post-nasal space and the sinuses, and X-Ray check being taken where necessary. Special points were a detailed history of any clearing trouble they might already have experienced, and an attempt to establish, visually, a positive Valsalva

Subsequent experience showed that a positive Valsalva can be seen by the experienced otologist in about 90 per cent. of subjects, but it also showed that by far the most reliable method of forecasting the otological fitness of a subject for diving is to examine his ears while under pressure increase, either in a compression chamber, or in the flood-up chamber of a D.S.E.A. Tank. (It is quite easy to improvise a waterproof headlamp, though attempts to examine ears while totally submerged were a persistent failure, due to difficulties of refraction.)

Thus it was hoped that a complete otological dossier of these trainees' underwater careers would shed some light on the problem. It is not proposed to include records, but reference will be made to some cases of interest.

Concurrently with this scheme, laboratory work was started at the National Institute for Medical Research, under the guidance of Dr. G. L. Brown.

The Royal Air Force otologists had just completed some pleasantly immaculate work on the bullae of cats, compressed at varying rates of descent from a pressure equivalent of 20,000 ft. of altitude to ground level, in which they had demonstrated gross congestion, hæmorrhage and exudate from the mucosa of the middle ear and the osseous portion of the tube, the swallowing reflex being abolished by the use of intra-peritoneal nembutal as an anæsthetic (2). At the same time, Wing-Commander J. F. Simpson had observed that it was possible to compress the tympanic membrane to a far greater degree when the membrane was compressed alone, i.e. *viâ* the external auditory meatus with a subject at atmospheric pressure than when the whole body was subjected to an increase of pressure, as in a compression tank when the subject failed to clear his ears.

Working from these observations, we conducted the following experiments, (quoted from R.N.P. 43-65, U.P.S. 31) (3).

1. The first step was to check Wing-Commander Simpson's observations, but additionally, compressing the drum at varying rates of increase, which were to be recorded. This was done by means of a pressure reservoir and needle valve, connected to a recording manometer and kymograph, also to the subject's auditory meatus, by means of a modified Siegle's speculum. The drum could thus be observed while being compressed. The subject was provided with a quick-release by-pass, which he opened on feeling pain, recording his threshold automatically on the kymograph.

Table 1 records the results and it will be seen that the threshold of the drum is generally slightly raised when the pressure rises rapidly. This is probably merely due to the delay of a fraction of a second in opening the by-pass when pain was felt, during which the pressure rose. Certainly the rapid increase of pressure did not lower the threshold, although several subjects' drums were compressed at a rate of increase far above the danger limits for charioteers. The table also shows a wide variation in the thresholds. This

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TABLE I

COMPRESSION OF TYMPANIC MEMBRANE VIA EXTERNAL AUDITORY MEATUS AT ATMOSPHERIC PRESSURE

SUBJECT		THRESHOLD		RATE OF RISE OF PRESSURE		PAIN		THRESHOLD		TIME		RATE OF RISE OF PRESSURE		REMARKS	
		PAIN	THRESHOLD	mm Hg	Approx Depth (ft)	Time (sec)	mm Hg /sec	ft Water /sec	mm Hg	Approx Depth (ft)	Time (sec)	mm Hg /sec	ft Water /sec		
BROWN	Ear														
	R	182	8	20			9 1	0 39	194	8	6	32 3	1 4		
GAY FRENCH	L	320	14	24			13 3	0 58	328	14	5	131 2	5 7		
	R	310	14	34			9 1	0 39	332	14	5	132 6	5 8		
MACKINTOSH	L	245	11	33			10 7	0 47	314	14	9	31 9	1 5		
	R	274	12	35			7 8	0 34	308	13	8	38 5	1 7		
ROGERS	L	245	11	17 5			14 0	0 6	248	11	3	82 7	3 6	Slightly apprehensive at first	
	R	234	10	36			6 5	0 26	242	10	4	69 5	2 6		
DOWNMAN	L	185	8	59			3 1	0 13	170	7	2	85 0	3 7		
	R	124	5	2-			5 6	0 24	208	9	6	34 7	1 5		
MARKS	L	330	14	17			19 4	0 84	338	15	2	169 0	7 7	Marks reached recording limit of manometer on fast run Dis comfort but no pain	
	R	344	15	48			7 2	0 31	338	15	1 75	193 0	8 4		



SUBJECT		A		B		REMARKS
		Mean of all thresholds taken at atmospheric pressure.	mm./Hg	Approx. depth in feet	Pressure in chamber at which pain in ears appeared.	
BROWN	R	182		8	140	6 ? Left ear to be tested (hurt this ear, when it "locked" during experiment).
GAY-FRENCH	L R	340 325		15 14	246	11 After 7 runs in day in chamber to threshold, threshold dropped to 178? due to residual tympanic oedema or diurnal variation.
MACKINTOSH	L R	245 274		11 12	170	7 Very good, confident subject, and exceedingly shrewd observer. Probably one of the most accurate readings.
ROGERS	L R	307 302		13 13	200	9 Was slightly apprehensive during early (a) tests ---now more confident.
DOWNMAN	L R	185 150		8 7	146	6 Very "vaso-sensitive" drums.
MARKS.	L R	370 + 370 +		16 16	214	9 Threshold (A) too high for manometer to record.
PRATT	L R	306 —		13	146	6 Right ear not tested due to mild otitis externa + wax. Apprehensive in in-chamber. Threshold (B) probably higher than 146.
BOYCOTT	L R	195 153		8 7	146	6 Old bilateral Schwartz. Difficulty in clearing.
DICKENS	L R	299 191		13 8	200 150	9 7 Right ear cleared inadvertently at 150. Has always cleared Right much more easily than Left.
PERGANDE	L R	370 + 370 +		16 16	272	12 Experienced diver. Was noticed to be swallowing in tank and was probably clearing to some degree inadvertently before he had reached his threshold.

## Oto-Rhinological Problems of Offensive Diving

corresponds with the known facts of practical diving. There was little to see through the speculum. On raising the pressure, the drum could be seen to be forced in and grow progressively ischaemic. On releasing the pressure it regained its normal position and there was slight vaso-dilatation, but nowhere as marked as in the mildest otitic barotrauma. It appeared then, that this experiment was by no means a laboratory reproduction of the conditions experienced by charioteers, and the next experiment confirmed this.

2 Here, the same subjects as before, with four additions, were subjected to an increase of general pressure in a dry tank and were told to refrain from clearing their ears, but to signal when they experienced aural pain. Table II shows that, in every case, aural pain occurred at a lower general pressure than that to which the drum could be subjected by itself, and, that the higher the threshold in Expt 1, the greater the discrepancy between the two thresholds. In other words, under general pressure, individual thresholds while still varying quite widely, varied less than the drum thresholds at atmospheric pressure. This suggested one of two hypotheses.

(a) That something other than the drum was being affected by the general pressure under the conditions of Expt 2, and having a lower threshold was "firing off" first.

(b) That general pressure, under the conditions of Expt 2, in some way lowered the threshold of the drum, as recorded in Expt 1.

3 A third experiment gave a clue as to which is correct. In this the subject was in a dry tank, with one external meatus occluded. The method was to smear the inside of the tragus with heavy grease and complete the occlusion with the finger tip. Incidentally, it is far more difficult to make the external auditory meatus pressure tight than one would suppose. On raising the general pressure, pain was experienced in the open ear at the figure recorded in Table II, Column B. On releasing the occluded meatus, pain was experienced in this ear. The pain was, of course instantly relieved by clearing. If hypothesis (a) had been correct, pain would have occurred in both ears simultaneously and the appearance of pain in the occluded meatus on allowing the pressure to impinge on the drum suggests strongly that hypothesis (b) is correct.

4 Wilson has recorded that there are three nerve plexuses in the tympanic membrane. One, the sub epithelial, has naked nerve endings ramifying among the epithelial cells, lining the outer surface of the drum. The middle plexus in the fibrous layer, connects with the sub epithelial and with the third, the sub-mucous plexus, lying between the fibrous layer and the mucous lining of the drum which of course, is part of the mucous lining of the middle ear. This sub mucous plexus, according to Wilson, contains Paccinian corpuscles. If the body is subjected to a rise in general pressure without clearing the ears, then the middle-ear cleft will be at atmospheric pressure while the blood vessels lining the middle ear will be at a pressure greater by the amount to which the outside pressure has been raised. When this difference becomes sufficiently great oedema of the middle-ear lining as has been shown by the R A F will be produced. Column B Table II, suggests that oedema is produced at a pressure difference of between 140 and 200 (max.) mm. Hg. Under these circumstances i.e. with the stretch receptors of the sub mucous plexus.

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membrane. "N" had a purple, antero-inferior hæmorrhage into the substance of both membranes, a doubtful Rinne and a Weber which was lateralized to right with marked loss of air conduction to the low tuning forks (Stage III, both).

He was rested for four days, after politizerization, and, when recovered, volunteered to repeat the performance with the recorder attached (since trim conditions, etc., were known). "C" was again the driver, and the only modification was to fit "N" with a non-operational suit, in which the vizor-type facepiece was replaced by a gasmask type, so that he could hold his nose on the way down. Fig. 2 shows the record of this, and it will be noticed that the Chariot hit the same ledge of rock.

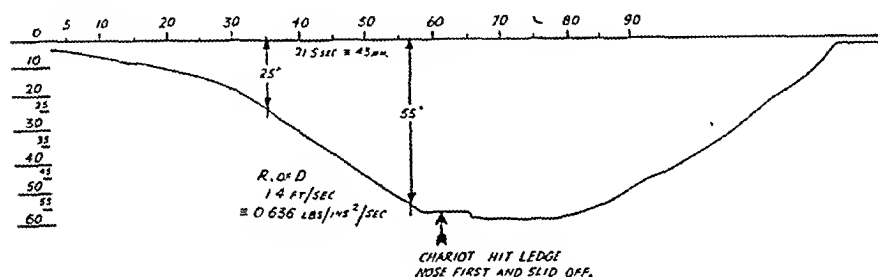


FIG. 2.  
Moderate crash dive.

"C's" ears again showed no change, and this time "N's" ears showed less damage, though there was a loss of 10 seconds to 64 dv. (A.C.) in both ears, with a Weber lateralized this time to the left (mild Stage III). The ears were normal again in 48 hours.

Later, similar dives by other members of the class, some of which were recorded, confirmed that a dive rate of 1.5 ft./sec. (34.5 mm. Hg/sec.), should be considered the safe maximum, and that it was better to keep the dive rate under 1 ft./sec. This was aided by modifications to the hydroplanes.

Examples of such ideal dives are shown in Figs. 3 and 4, made by two operational divers.

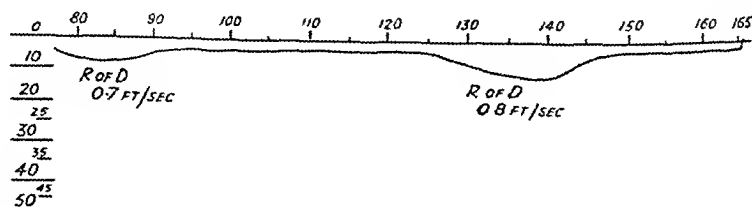


FIG. 3.  
Chariot. Surface runs, showing R. of D's of 0.7 and 0.8 ft./sec.

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A possible variable was considered at this stage, i.e. the effects of apprehension or the cumulative effects of fatigue on the pain threshold. The former was most difficult to assess, but that there may be, perhaps,

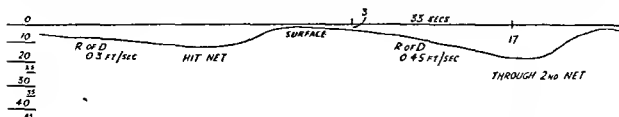


FIG 4

Chariot Normal runs Approach to and passage through A/S nets

something in the latter is shown by the following extract (5), though due to the exigencies of war it was never possible to investigate this as fully as was hoped

On one occasion I subjected my own ears to seven runs in a dry chamber in one day, on each occasion delaying clearing until there was appreciable pain, and found that, on the last run, my threshold had dropped from 246 mm. Hg to 178 mm Hg. This may have been due to residual œdema after each run, cumulative in effect, but experiment, at present incomplete, suggests that there is a marked daily variation in the threshold and that it can be affected by a multitude of external influences—fatigue, apprehension, etc.

The greatest number of aural casualties, however, occurred in Class A, where diving was at least once every 24 hours. This improved in Class B, where the diving interval was lengthened. I notice also, that P o W Italian charioteers (S L C s) state, though somewhat vaguely, that practice takes place "about twice a week". Whether this is for aural reasons, I do not know. For these and also for psychological reasons, I think that the 40-hour interval between dives as laid down by Captain S 12, is desirable. Under the present requirements of training, however, it appears to be impracticable. Nevertheless, taking into account the exigencies of war, I think the present arrangements are satisfactory and safe. They are made so by the very careful "nursing" of embryo charioteers by the team at present operating in H M S "Titania", both by the training officers and the Medical Officer. Aural damage or tiredness causing the diver to be stood off for an appropriate period.

At the same time, experiments were made with a type of nose-seal, connected with a Politzer bag in the neck of the suit, whereby the diver could obtain a small positive pressure boost, as in politzerization, and after much trial and error, a Dunlop nasal anæsthetic mask, modified, was found to give the best results. This apparatus was not proceeded with in the case of the charioteers, for while on an operation they would have both hands employed in handling the machine.

The last, and probably the most valuable prophylactic measure to be adopted, was to incorporate into the curriculum of training (from the beginning) tubal muscle drill. The trainees were taught to perform

Valsalva at atmospheric pressure, then under positive pressure, then, again at atmospheric pressure, holding a dummy mouthpiece in their mouths and without holding the nose, and lastly in the suit itself, both on the surface and while descending. Also, it was made very clear to them, that, while descending, the longer they delayed clearing the more difficult it would be. The greater the pressure differential in the middle-ear cleft, the greater will be the œdema in the osseous portion of the tube and therefore the more difficult it will be to pass air past the isthmus.

In fact, in some (but not all), there comes a point when they "lock" and no amount of tubal muscular manipulation or expiratory force will get air to pass, and the only way is to release the pressure, i.e. to surface.

This is serious in an operation, where a diver, surfacing at the entrance to a harbour would reveal to the defences that an operation was in progress and, inevitably, would initiate depth charge counter-attack, killing the other divers.

We were, incidentally, unable to confirm the statement of Armstrong and Heim that it is impossible to clear the ears against a pressure in excess of 90 mm. Hg (6). It is quite clear from Table II that this is not so, and that the "locking" point is a matter of individual variation.

The exigencies of war prevented an investigation as to whether, at a given rate of pressure increase, aural damage is more intense when the subject is using pure oxygen as against compressed air or a gas mixture, but comparisons between the charioteers and divers using compressed air suggest that this may be the case.

The results obtained by introducing the various safety measures described above were satisfactory. Observations on classes taken over the autumn, winter, and spring of 1943-44 showed that the incidence of aural damage had been halved, in spite of the higher incidence of nasopharyngeal infections to be expected during this part of the year, and it was considered that the situation was controlled as far as it was likely to be, taking into account the conditions under which these men worked.

Sinus barotrauma occurred among these divers, but in a less proportion than the otitic, the pathology and mechanics being precisely the same.

One diver sustained a hæmatoma of the right maxillary antrum with anæsthesia of 13 and 14, which cleared however, with conservative treatment.

### Ascent Rates

These were not a problem from the aural point of view, for the Eustachian tube acts as a one way flutter-valve, so that excess pressure in the lumen of the middle ear will bubble out automatically at any rates of ascent the diver is likely to attempt. The writer has surfaced

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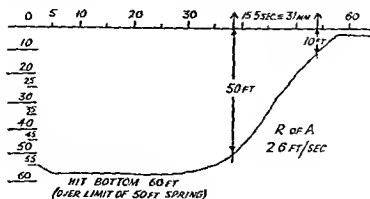


FIG 5

at 2.6 ft-sec with no ill effects (Fig 5), and in the case of three men escaping from a sunken submarine at 210 ft using the D S E A, the surviving two reported no aural symptoms, the third being killed from too rapid ascent, and a consequent burst lung

## Concurrent Investigations

In the summer of 1943, H M S "Truant" arrived in Loch Corrie to carry out experiments on launching Chariots from a submarine at depth. As the main problem appeared, from the above investigations, likely to be mainly aural in other words, the maximum flood-up rate with a diver in the D S E A Chamber would be dictated by his ears and sinuses, the following two reports are appended, Report (7) made at the time, and a later report showing the solution to the problem (8)

The desired technique was to be this H M S "Truant" was to lie on the bottom at about 50 ft and three divers in Sladen suits, would escape from each of the D S E Chambers and release a Chariot from each of two containers, fitted on the fore and after casings. These containers were tested to 300 ft, and could be flooded or blown from the interior of the submarine, as desired.

After releasing the Chariots, two of the divers would drive off to carry out their operation the third diver of each team would re-enter the submarine, by way of the D S E Chamber, and the submarine would then proceed to the waiting area.

The ends of the containers were sealed by watertight doors, opening to port and secured by butterfly clips.

Dummy runs on the surface quickly proved that there was only room for one diver at a time in each chamber, and some misgiving was felt as to the weight of the container doors, which, on the surface with the submarine on an even keel, required at least two strong men to close them.

On completion of these, it was decided to try a run at depth with the recorder in lieu of the diver, in order to find out at what speed it was possible to flood up, as time was of great importance in the operation.

This was done on the afternoon of 25.5.43, with most startling results. The submarine was on the bottom, showing 48 ft on the gauge. Fig 6 shows the result of opening both floods full, closing them when the pressure had

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equalized, opening both vents full (inboard) and then completing the flooding with both floods, again, full open. This is obviously most undesirable. The initial R. of D. is 1.1 ft/sec. and with the added bulk of the diver in the

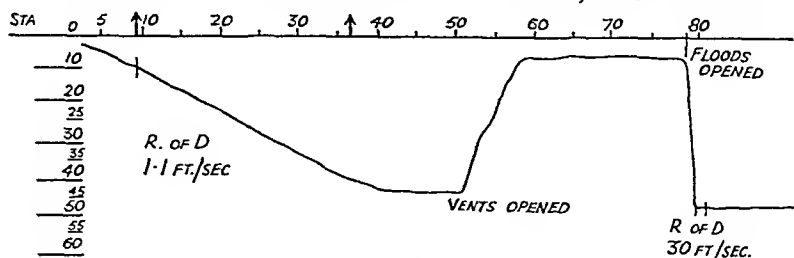


FIG. 6.

Both floods, both vents. "Truant" 25.5.43. Recorder only in chamber.

chamber, this would rise to (in the region of) 1.5 ft./sec., or faster than a moderate crash dive on a Chariot. The figure also shows the necessity for gentle manipulation of the inboard vents and the final flooding up, for a R. of D. of 30 ft./sec., from the first atmosphere, would undoubtedly kill the diver.

It was decided, therefore, to use only one flood and vent. Fig. 7 shows

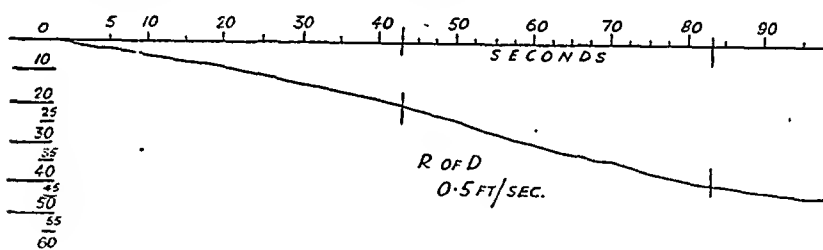


FIG. 7.

One flood, one vent. Recorder only in chamber. "Truant" 25.5.43.

he result of this . . . The R. of D. is now 0.5 and Fig. 8 is under the same circumstances, but with the diver in the chamber. It will be seen that his bulk pushes the R. of D. up to 0.8 ft./sec., and this is quite reasonable. The flood was opened full in both of these runs and following Fig. 8, the diver opened the hatch and proceeded to the surface.

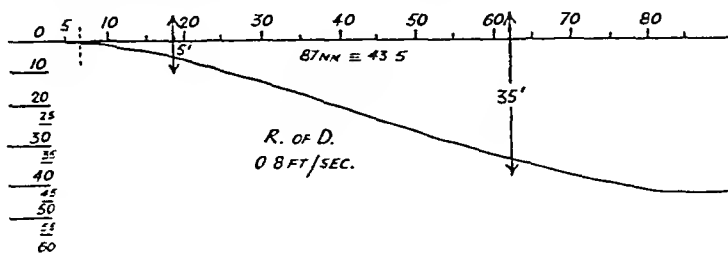


FIG. 8.

One flood, one vent. Diver in chamber. "Truant" 26.5.43.

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A further run was then done, with the recorder only in the chamber, on the process of draining down. This was most alarming (Figs 9 and 9A). The recorder, which is of sturdy construction, received such a jolt that the stylus was shot over the zero line, and the rate of ascent was 46 ft in 2 seconds, and, allowing for recorder lag, probably in excess of this.

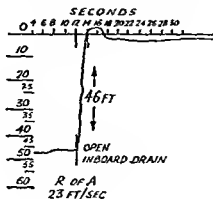


FIG 9

Drain down D S E Chamber Flood valve closed Truant 25 5 43

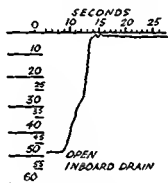


FIG 9a

Check run on Fig 9 Drain cracked as gently as possible but with flood closed.

The reason is, of course, obvious. Assuming an inelastic chamber, full of water at  $2\frac{1}{2}$  atmospheres and assuming that the escape hatch is tightly closed the removal of an infinitesimal quantity of water will cause the pressure to drop to that in the submarine (1 atmosphere) in an equally infinitesimal time, since water is virtually incompressible. In point of fact, the escape hatch was watertight, being only held down by a toeclip and this and a certain amount of lag in the recorder, accounts for the record not being more alarming than it is.

Since a D S E Chamber is designed for egress from a submarine and, as far as I know, nobody has ever before entered a submarine at depth, this drawback has been foreseen by nobody, and it is considered that the use of the recorder saved a diver from, at the least, very severe injury to his lungs and irreparable injury to his drums, and probably from an unpleasant death.

The problem was tackled by draining down, using the following technique

- 1 Diver enters chamber and closes hatch
- 2 Flood valve opened to full extent



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3. Inboard drain "cracked" carefully, watching gauge, but is not more than "cracked".
4. Throttle down on floodvalve, cautiously. If pressure falls too rapidly on gauge, open flood.
5. As flood is closed, pressure falls to zero, after which drain can be opened fully.

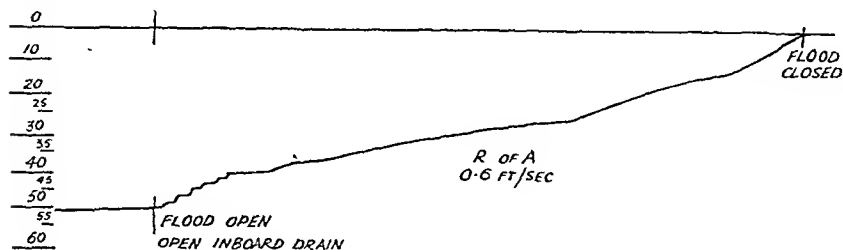


FIG. 10.

"Truant" 26.5.43. Drain down D.S.E. Chamber by technique described in text (Flood open).

Fig. 10 shows the results of using this technique, with the recorder only in the chamber; Fig. 11 is with the diver in the chamber and on this occasion an airbottle had been fitted to the side of the chamber, as an additional precaution, to act as an airlock. It did not seem to make much difference, possibly because the bore of the pipe (3/15 in.), leading to the bottle, was too small.

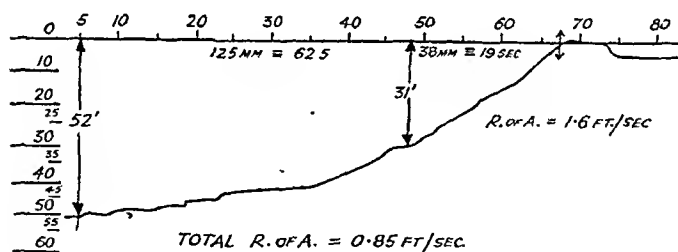


FIG. 11.

As for Fig. 10, but diver in chamber and air bottle fitted.

Successful escapes and entries into the submarine were carried out after this.

The implications of the report above were discussed at meetings of the Underwater Physiology Sub-Committee and the flood-up rates were accepted, and at the same time it was suggested that the fitting of a 7/16 in. stopcock to the chamber might obviate the very complicated drill needed to drain down the chamber without killing the diver inside.

This proved not to be so, and the following extract from a later report (8) explains why. The attached pressure curves show that the problem had been effectively disposed of.

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Conversations with Captain S 12 and Commander (S) and the Engineer Officers of H M S "Cyclops" suggested that the pilot cock on its own (as recommended by the U P S) was unlikely to be 100 per cent safe and that it would be a very simple matter to fit an airlock, in the form of a chord of the circumference of the chamber. This was fitted in the after escape chamber of H M Submarine "Tribune" on the afternoon of 20 8 43. It was therefore decided to try both methods.

The dimensions were as follows

Capacity of escape chamber	.	..	51	cubic feet
Capacity of air-lock (with pipe)	.	.	1	46 cubic feet
Bore of pilot cock	..		7/16ths	inch

At the same time, the pilot cock was fitted to take a blank copper washer, which, if desired, could be reamed out to any size, up to the bore of the cock.

The trials were carried out in Kames Bay at a depth of 38 ft on 21 8 43.

The method of flooding the chamber, in order to ensure that no air, apart from that contained in the air lock, remained in the chamber was as follows.

Recorder in chamber, started, door closed.

Hatch securing clip raised, off toe clip flood started.

This, when the pressure became sufficient raised the escape hatch, flooding the chamber completely. The hatch was then closed and the experiment proceeded with.

Fig 12 shows a drain down, deliberately opening the drain wide. The result is not desirable, the rate of ascent being 5.6 ft/sec, though the air lock has dropped the rate from the 23 ft/sec recorded during the same procedure in "Truant".

Fig 13 shows a drain down, exercising moderate care, with unskilled operator in charge of drain valve (myself). The result is better, an overall rate of descent of 2.3 ft/sec, but with a somewhat steep gradient in the middle of 3.5 ft/sec, due, presumably, to inexperience.

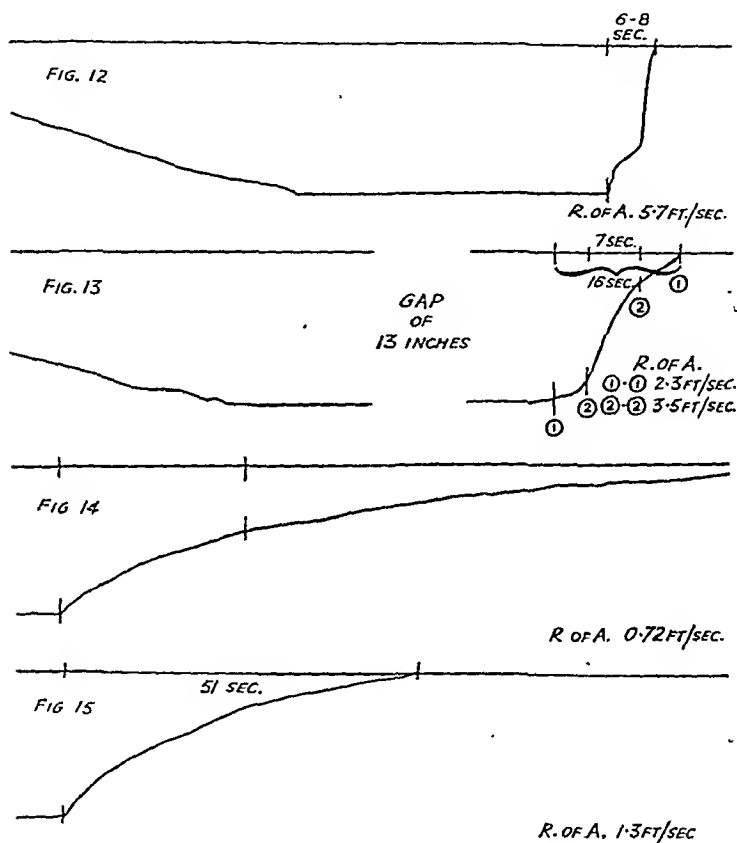
Fig 14 is the same, but with a Chief E R A operating the valve. The difference between the skilled and unskilled operator is well shown, the rate of ascent being 0.72 ft/sec.

Fig 15. In this case, the pilot-cock was opened first, the drain only being opened when the pressure on the gauge, fitted to the chamber had fallen to zero. This is perfectly satisfactory, the rate of ascent being 1.3 ft/sec.

I do not consider the use of only a pilot cock practicable or safe. The actual escape hatches, when secured only by a toe clip as during operations such as these are never completely watertight, nor are meant to be. They vary in the efficacy of their seal in different submarines and in any case might be distorted by accident or enemy action. This variation, were airlocks not to be fitted, would mean that each individual pilot cock would have to be a different bore discoverable only by experiment much smaller than the 7/16 in used and, therefore, liable to choke. This was demonstrated in Fig 13 where it will be noticed that there is a long period of steady pressure at 38 ft. During this period the cock was open, but made no difference to the pressure, the reason being ultimately discovered to be a slightly leaking flood valve (in this case, though a leaky hatch would have the same effect).

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The use of an air-lock "smooths out" the whole procedure, and is, I think, an essential part of any safety device, such as this. On the other hand, using the ratio of air/water of 1.46-51.0 (see air-lock and chamber capacities, above) it is still possible to produce dangerous rates of ascent, as in records 12 and 13 (though 13 would be only, I think, uncomfortable). This is due, obviously, to the construction of the existing drain, which was never intended for operations



DEPTH OF EACH DIVE — 38 FT

such as these. It has a wide bore (4 in.) and a coarse thread, and it was intended, originally, to drain the chamber as quickly as possible, without regard to pressure changes. The provision of what is really a smaller preliminary drain, the pilot cock, makes the operation, in this case, foolproof. The combination of the two, therefore, appears to be ideal, if this is not considered too complicated. The drill, however, is absolutely simple . . . "Hatch closed (as before), on cock, when pressure is zero on gauge, open drain as widely as desired."

Should, however, the combination be thought too involved, the air-lock,

# Oto-Rhinological Problems of Offensive Diving

of the two devices, must be retained. To eliminate the pilot cock, the air/water ratio would have to be increased considerably, using the existing type of drain valve. In view, however, of the small number of submarines still fitted with the escape chamber and the simplicity of fitting the above apparatus (in the case of the "Tribune", under one day's work), the combination of the two appears to be an economical proposition, as far as Chariot work is concerned.

## Amyl Nitrite as an Aid to Clearing

Mention must be made of this substance, as some work was done on its action on nasopharyngeal mucosa. A report had been received from Australia that the inhalation of this drug aided the passage of air into the Eustachian tubes. Experiments were therefore carried out both at Hampstead and under practical diving conditions, in case it might prove to be a ready-made answer to the whole problem.

Ephedrine, adrenaline, etc., had already been proved to be so ineffective as to be useless, operationally, and tuamine and its associated chemical cousins were not then available.

Preliminary trials on the writer showed that it was dangerous to dive immediately after inhaling the contents of a capsule and that, in fact, during the period of vaso-dilatation, clearing was impeded, and that if benefit occurred, as the majority of divers alleged it did, the drug must be inhaled from half to one hour before diving.

Experiments in Hampstead, with passive inflation of the Eustachian tubes, *via* a Gage type mask, connected also to a kymograph, confirmed this, but the benefit was so slight, and the potential dangers so great, when used without medical supervision (as the drug would have been on an operation), that it was decided not to proceed further with the idea.

The mechanism, was presumably, the reverse of adrenaline, that is a primary vaso-dilatation followed by a reactionary vaso-constriction of the nasopharyngeal mucosa, but insufficient work was done in this field to permit of more than theorization.

## Summary

- 1 The oto rhinological problems of offensive diving, with special reference to the Human Torpedo are described, as are the experiments performed and the apparatus used.

- 2 Various subsidiary problems and their experiments having a bearing on ears and sinuses are also described.

- 3 Various solutions to the problems are discussed, including the one eventually adopted.

- 4 It is felt that there are aspects of the ear clearing problem which are by no means complete and that further work on such subjects as the effect of fatigue and the exact mechanism of clearing in the trained and untrained subject would be fruitful.

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I would like to express my very great appreciation of the help I received, not only from the experts mentioned in Paragraph 1, but also from my executive colleagues, in particular Commander W. Shelford, D.S.C., R.N. and Lieut. Chadwick, R.N. Also to otological and physiological colleagues in the Royal Air Force, with whom I discussed as many of my difficulties as secrecy would at that time permit. I would like to thank the Medical Director-General of the Navy for permission to publish this article.

### REFERENCES

Certain abbreviations have been used, namely:

R.N.P.—Reports of the Royal Naval Personnel Research Committee.

U.P.S.—Underwater Physiology Subcommittee of the above.

F.P.R.C.—Flying Personnel Research Committee.

(1) GAY-FRENCH, *R.N.P.*, 43-41, *U.P.S.* 19.

(2) MCGIBBON and CAMPBELL, *F.P.R.C.*, 557 (and see also McGibbon, *J. Laryng. and Otol.*, lvii, 344-350, July, 1942).

(3) GAY-FRENCH, *R.N.P.*, 43-65, *U.P.S.* 31.

(4) WILSON, GORDON, January, 1911, *Amer. Journ. Anat.*, xi, 101, *et seq.*

(5) GAY-FRENCH, *R.N.P.*, 43-65, *U.P.S.*, 31.

(6) ARMSTRONG and HEIM, *J. Amer. med. Ass.*, cix, 137, 417-421.

(7) GAY-FRENCH, *R.N.P.*, 43-41, *U.P.S.*, 19, Section E.

(8) GAY-FRENCH, *R.N.P.*, 43-61, *U.P.S.*, 24 a.

# FENESTRATION OF THE LABYRINTH

By O POPPER (Johannesburg)

## PART II

### Transtympanic Fenestration

PART I of this paper (*The Journal of Laryngology and Otology*, January, 1946) of necessity covered a somewhat large canvas. The ensuing description is intended to fill in and accentuate important details.

My greatest problem in carrying out the transtympanic approach was not the instrumentation—for this ophthalmic, dental, and other standard instruments were found most suitable—but the question of

- 1 Illumination
- 2 Stereoscopy
- 3 Magnification

The hazards inherent in this work are formidable, but under control as long as the surgeon can see. The headgear I use, is therefore described and discussed in detail at the very beginning of this paper to emphasize its primary importance. It would be purposeless to give operation directives without it. They could not be carried out without grave risk. Unhappily in this surgical procedure there is no allowable margin of error.

Needless to say my headgear is only one solution. I trust that, with the co-operation of optical manufacturers overseas, my colleagues will improve it.

#### ILLUMINATION

Illumination must of necessity be intense for small landmarks, and where magnification is used. This brilliance must also be accompanied by high quality. Finally the beam must be as near as possible perpendicular to the field—or in other words on a level with, and between the eyes.

Stereoscopy is imperative when working in depth and to such close limits. One cannot orientate without a three dimensional view of this small operating field. It would be courting disaster to attempt this work without equipment capable of meeting these demands.

Magnification is desirable, but if illumination and stereoscopy are assured, it need not be of high order. The operating microscope is without question the answer.

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I have built one around a Leitz binocular dissecting microscope. Some training is required when operating, to adjust oneself to differences of perspective which such an optical system imposes. The main drawback to the operating microscope is its relative immobility.

A binocular headgear using prisms for convergence and stereoscopy, incorporating an intense light source, possesses the advantage of flexibility.

Needless to say neither its magnification or illumination could be expected to be of the high order of the static microscope, but the ability to look into every nook and cranny and around a structure is a very real advantage.

The accompanying drawing illustrates the headgear I have devised for this work. It is built around an old Wessely mounting.

Prisms (Fresnel Rhombs) are employed whose front (objective) faces are close together. The prisms are adjustable, so that the parallel eye faces are set to the surgeon's interpupillary distance. This means that the surgeon looks straight ahead at infinity when viewing his field—the prisms accomplish the convergence. This is most restful and banishes visual fatigue.

A 4 dioptre lens in front of the objective faces of the prisms gives about  $1\frac{1}{2}$  magnifications and a working distance of  $6\frac{1}{2}$  inches. With conventional telescopic spectacles the eyes must converge on the field—a strain I find almost intolerable after the first 45 minutes.

The proximity of the two objective faces is vital. One operates in a funnel about 35 mm. deep, and 15 mm. wide at the top. The conventional telescopic spectacles are unsuitable, because its units are 60 mm. apart, and one or other eye constantly loses the field. The surgeon's head is always moving. By placing the objectives close together stereoscopy is easily maintained. The eyes must be pampered in this operation.

By adding a Galilean system suitably corrected for chromatic aberration to these prisms, I hope to achieve between 3 to 4 magnifications and a working distance of 9 inches.

I am indebted to Professor H. H. Payne of the Department of Physics, Witwatersrand University, for computing the optical formulae and calculations.

The illumination device is of conventional design with certain modifications. The aluminium lamp housing has a diameter sufficient to accommodate a Mazda 88 bulb, as used in the Bausch and Lomb Ortholite. (The ortholite is fitted to my Binocular Leitz operating microscope.) The condenser and  $45^\circ$  reflector are also Bausch and Lomb units. It is important that optical equipment of repute, be used. A cheap condenser will project patterns of light of differing intensities which are most disturbing.

# Fenestration of the Labyrinth

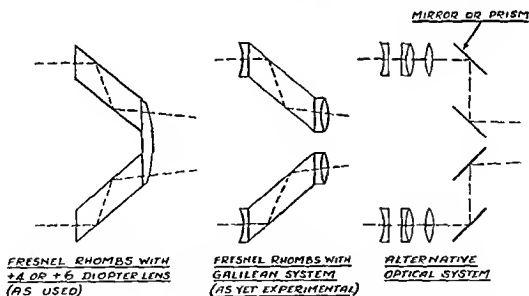
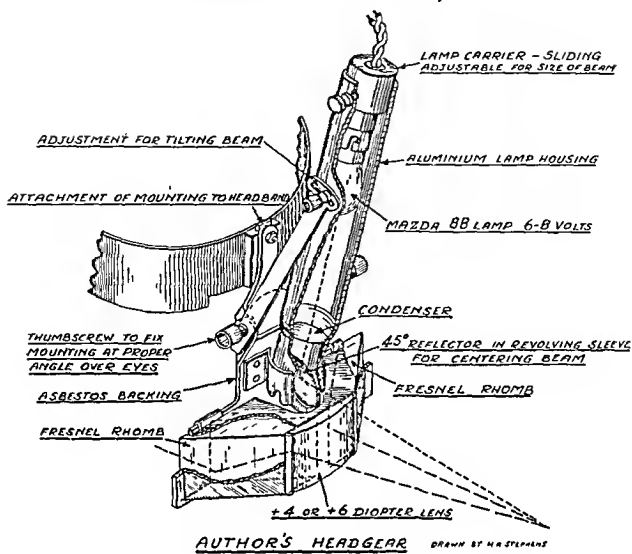


FIG. 1.

Professor H H Payne, Department of Physics, Witwatersrand University, has computed the following calculations where Fresnel Rhombs are spaced within a Galilean system for a 9 to 10 inch working distance

Magnification	Objective achromatic plano-convex	Eye piece plano-concave
3	+25.8 (dioptries)	-66.8 (dioptries)
4	+27.7	-95

plane faces in contact with faces of Rhombs and cemented.



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This unit projects a clear white field of light of magnificent and uniform intensity almost perpendicular to the field. The light field can be increased or contracted by sliding the lamp holder down or up respectively in the housing, and fixing it with a convenient thumbscrew. Adjustments are also provided for tilting and centering the beam. Once these adjustments are made they remain a fixture, and need not be repeated or altered.

This device gives an infinitely better quality of light than the Clar headlight. The Clar is worn too high above eye level. Its main beam strikes the field obliquely. Its unshielded bulb has evoked protests from my sister and assistants who were forced to suffer its blinding glare for an hour or longer. The triad, intense illumination (perpendicular), stereoscopy and magnification, is the keystone to the entire instrumentation.

With practice it will be found that the operating microscope becomes a standby—the whole operation from start to finish can usually be completed without recourse to the microscope. However the microscope remains the sheet anchor should the surgeon lose his way or landmarks.

The accompanying plates illustrate transtympanic fenestration of the anterior face of the vestibular dome.

The operation falls conveniently into eight stages and should be carried out in the exact order given, with meticulous attention to detail. I would ask my colleagues' indulgence if I seem to stress this latter point in the ensuing description. I emphasize and underline them, because I believe their observance is vital to the success of the operation.

### ANÆSTHESIA

Local anæsthesia is advocated in the conventional operation because it reduces bleeding. This latter consideration does not loom large in the transtympanic procedure. I am biased against local anæsthesia as I find a patient's interjections a disturbing element in the atmosphere of tranquillity in the theatre—more important than ever in this class of work.

The choice of anæsthetic may be left to any competent anæsthetist. The patient must at no stage be congested as this may cause troublesome oozing. If this precaution is observed the operation is for practical purposes, bloodless.

My patients have had any of the following

Open ether and oxygen.

Pentothal induction followed by open ether and oxygen.

Pentothal induction followed by intratracheal ether and oxygen.

Intratracheal ether and oxygen.

Continuous pentothal.

# Fenestration of the Labyrinth

I have found all these measures entirely satisfactory. Clearly the emphasis is on the competence of the anæsthetist rather than the choice of anæsthetic.

## POSITION OF PATIENT

The patients' face is turned towards the surgeon and this relative position is maintained from the start to finish.

The skin is prepared in the usual way. The hair from the temporal region is shaved. It is unnecessary to remove any hair from the mastoid-parietal-occipital area. The meatus is filled with rectified spirit.

The incision is marked out in brilliant green—a line running vertically down for about an inch and a quarter immediately in front of the tragus from the incisura tragi to a point somewhat in front of the lobule.

This line lies in a natural fold in the skin between the tragus and the temporo-mandibular joint.

In Part I of this paper I suggested placing the incision on the edge of the tragus or just within it, as so to conceal a resultant scar. This precaution is quite superfluous as the scar from the incision indicated is an almost invisible hairline after two weeks if fine skin sutures, placed close together, are subsequently used. The advantage of the external incision is that, it not only saves time, but one starts off by being a quarter of an inch or so closer to the field.

The temporo-mandibular cleft is now infiltrated with a solution of saline containing 6 to 8 minims of adrenaline (1 in 10,000) to the ounce. A fine needle is used. Note that the point is directed backward so as to hug the lamina tragi during the whole injection. One puncture, rarely two, is sufficient.

The incision is made along the marking, now somewhat distorted by the injection. The edge of the scalpel is directed towards the tragus. The cut is made down to, but not through its perichondrium. The edges of the incision are gently separated by a small mastoid retractor. From now onward the operation may be conveniently described as falling into eight stages.

## STAGE I *Exposure of the tragal cartilage and the cartilage of the external auditory meatus*

Applying gentle traction, the anterior surface of the tragal cartilage is freed with scleral scissors, small snips separating fibrous connections between the perichondrium and its overlying fascia. The points of the scleral scissors are directed towards the cartilage.

Once this is achieved, it provides a "point d'appui" for the insertion of the closed blades of a medium-sized Kilhan speculum. The blades are gently opened, and the whole tragal cartilage is cleared in very short time.

The tragal cartilage is continuous with the antero-inferior portion of the cartilage of the external auditory meatus, the latter bending sharply backwards. As this portion of the perichondrium will not have been reached by the infiltration it is as well to infiltrate again.

Spreading the Killian speculum gently straightens out the bend, and with short snips of the scleral scissors directed towards the cartilage the whole of the latter is exposed down to its attachment to the edge of the tympanic plate. The periosteum of the latter is infiltrated.

An incision along its edge is made, and the periosteum reflected with a tiny elevator.

The closed Killian blades are placed between the periosteum, and the denuded tympanic plate and gently separated. The latter must be done gently as rough handling may cause rupture of small veins in the temporo-mandibular fossa. Should this occur packing with narrow ribbon gauze soaked in thrombin controls it instantly. *Do not forget to remove this gauze strip before the skin is sutured.*

Here, be it noted, that the operator has worked thus far in one fascial plane, without cutting across any structure of importance. The tympanic plate should be exposed for just over a quarter of an inch.

#### STAGE II. *Separation of the cartilage from the edge of the tympanic plate.*

After devising a special instrument for this manœuvre on the cadaver I discovered, by accident, a very simple way of doing this on the living subject.

Having exposed the cartilage at its attachment to the tympanic plate, the tips of the Killian blades were at this precise junction. Before withdrawing them my co-ordination must have become inverted because instead of allowing the blades to close I pressed the shanks and opened the blades further. To my great satisfaction, I saw the attached edge of the cartilage literally gliding off the edge of the tympanic plate revealing the skin inside the meatus and a tiny segment of the drum itself.

This then is the technique for Stage II of this operation. Small slivers of broadish cartilage remain on the edge. They are removed in Stage III.

#### STAGE III. *Removal of portion of the tympanic plate.*

A long-bladed self-retaining mastoid, or similar retractor is now employed. The posterior blade engages just below the free edge of the cartilaginous meatus and flattens the latter out against the bony posterior wall. The anterior blade pushes forward the fascia separated from the cartilage, plus the continuous periosteum separated from the tympanic plate. The temporo-mandibular joint plus anterior tissues are pushed forward "en masse".

## Fenestration of the Labyrinth

The drum is the vital landmark in Stage III It lies "square on" behind the tympanic plate

Using a small jawed rongeur the edge of the tympanic plate is nibbled down until the beautiful, shiny mother-of-pearl like drum and malleus are exposed to view A quarter of an inch is usually enough The sides require some trimming They are broad based They may be ground down with dental burrs so as to provide sufficient access to the tympanum

Recently I tried Reiter's automatic mallet and found it excellent It is used by oral surgeons The advantage is that one can regulate both the throw of the chisel to a fraction of a millimetre, as well as the force of the blow The cutting edge is placed on the surface of bone to be removed Pressing the release—thus using one hand only—the bone is cut, advancing a predetermined distance and under absolute control

I am indebted to my brother, Mr Frank Popper, L D S , M S D , for this suggestion and also for initiating me into the art of using a dental machine and the properties peculiar to various burrs

A little more than the posterior half of the drum is now exposed

### STAGE IV *Fashioning of the tympano meatal flap and exposure of attic wall and middle-ear contents*

The skin of the meatus is infiltrated subperiostally with a fine dental needle

An incision about half an inch from the drum down to bone is made sweeping around the remaining portion of the bony meatus

With an ophthalmic curette the skin is gently reflected from the meatus In the upper region where the tympanic and temporal portions fuse, there is a band of fibres anchoring the meatal skin These are severed with fine ophthalmic scissors By working all the way round, the skin is folded over the drum, its periosteal surface facing the operator It will be found that superiorly the skin is thicker than inferiorly where it has the texture and consistency of silk

The meatal skin and drum become continuous at the tympanic ring

The posterior segment of the latter must now be detached from the sulcus tympanicus so that the meatal skin plus the posterior half of the drum may be folded over the handle of the malleus

With the ophthalmic curette, using gentle strokes, this is accomplished without difficulty The sharp edge of the curette is at all times directed towards the bone Within a matter of minutes, the superlative landmarks in the middle ear lie revealed

The meatal skin plus attached drum, are gently tucked into the recess between the remaining portion of the tympanic plate and the anterior part of the drum

The greatest care must now be exercised that the burrs subsequently

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to be used do not tear the tympano-meatal flap to shreds. All the surgeon's attention must be focussed on this possible accident.

Only diamond burrs should, in my view, be used. They should have short heads, and they must at all times be directed away from the tympano-meatal flap. With diamond burrs the surface of bone is only touched—no pressure is required or desirable. They are far less *damaging to soft tissues*, should they be accidentally touched, than cutting burrs. Diamond burrs are only effective at high speed and the dental machine used must be capable of this. I prefer the cable-arm to the belt and pulley type because the former can be enclosed by a sterile sausage of linen.

One advantage of the belt and pulley is its immediate stoppage when the switch is released, whereas the cable arm type slows down to a stop. The surgeon operates the dental machine by a foot switch gear.

When the tympano-meatal flap has been folded over the malleus, these magnificent and beautiful structures stand out

(a) The long process of the incus attached to the capitulum of the stapes, with the stapedia tendon posteriorly forming a right angle with it.

(b) The crura of the stapes descending into the fossula of the fenestra ovalis.

(c) The chorda tympani nerve running across the long process of the incus at the upper edge of the tympanic field, to disappear behind the neck of the malleus.

These are the landmarks that concern us immediately.

The round window, the promontory and all the tympanic structures are there for the seeking.

The bony wall of the meatus immediately above the long process of the incus, and concealing the body of the latter, is the outer attic wall. It has already been stripped of its integument at this stage of the operation.

### STAGE V. *Removal of attic wall and exposure of incus.*

A cylindrical diamond burr of  $1\frac{1}{2}$  millimetre diameter is used. Its face is placed on the attic wall just above the long process of the incus. The object is to drill a hole right through the attic wall to reveal the continuation of the incus in the attic space. The burr is held rock steady over the indicated area—*making sure that the tympano-meatal flap is tucked safely away*—before the foot switch gear is depressed. A socket for the burr is formed. All bone dust is removed. The burr is replaced in the socket and very soon a slight give is felt as it penetrates the attic space. No pressure is used—debris is cleared. Through the drilled hole the incus can be seen. The edges of the hole are now

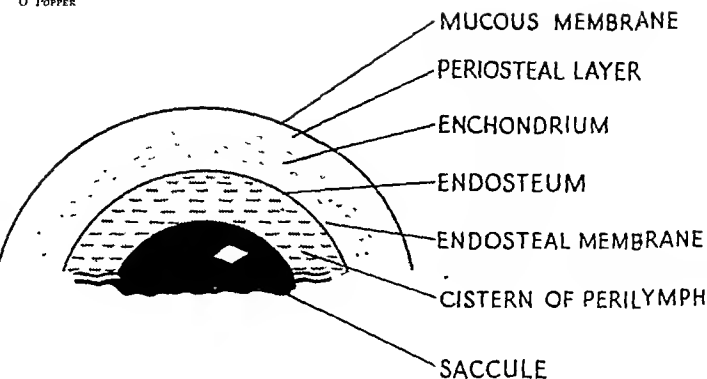


FIG. 2.

Schema of dome (anterior face) fenestration (diagrammatic). Advantage is taken of the dome curvature. It is ground down flat (enchondralization), the burr never enters the labyrinth cavity. The fistula becomes larger as the flat grinding process proceeds. Its edge is sharp and thin and is on the surface, not in a trough. It is surrounded by enchondrium. The periosteal layer is relatively remote.

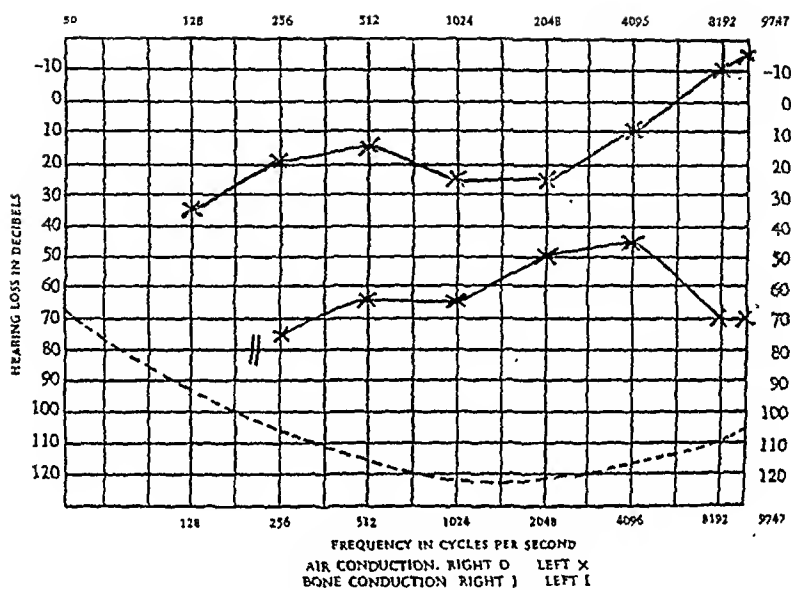


FIG. 3.—Audiogram of Mrs. D. Age 32. 8.11.46. I. Ear.

## Fenestration of the Labyrinth

enlarged until the attic wall has been taken down in all directions. The body of the incus, its short process attached in the antral region, and its articulation with the head of the malleus anteriorly are now exposed.

This reaming is continued. The side of the diamond burr is applied to the edge of the attic wall. The tip of the burr does not touch the now visible incus, which is in its normal position and acts as a natural guard for the facial nerve and the dome of the vestibule.

The thin bridge of attic wall below, adjacent to the chorda tympani, comes away with a touch of the burr. Any sharp projections are touched down—and the whole attic lies open. Apart from the minute amount of bone taken away in the fenestration this completes the gross bone removal—all non-pneumatized bone—the tympanic plate and attic wall. Its sum total is insignificant, a fraction of that when the mastoid is everted. The cut surfaces are close to epithelium and mucous membrane, and will cover rapidly.

I have had no otorrhœa in my cases—barely a serous discharge for two weeks. I believe the minimal destruction of bone to be responsible for this.

I refer to my first paper where I suggest this operative procedure for chronic attic suppuration where this is accompanied by mastoid sclerosis. Nature in such cases, has sealed off the infective process from the mastoid but cannot deal with the wide spaces of the attico-antral region.

This direct attack on the attic by the transtympanic route without opening the healed mastoid and exposing it to re-infection will, I am convinced, hold its place in operative otology.

### STAGE VI *Removal of the incus and exposure of the dome of the vestibule and facial canal*

With a fine needle—again ophthalmic—the main attachments of the incus are severed. They are

- 1 The short process in the antral region—a mere touch suffices
- 2 The lenticular process articulating with the capitulum of the stapes—again a light touch is enough

Very frequently these two attachments will be found to have come adrift of their own during manipulation of the incus when clearing the attic wall.

There remains then the incudo-malleolar articulation. The fine capsule is torn through with the needle with ease. The incus now lies loose in the attic. The chorda tympani is still seen crossing its long process. The incus must now be delivered, as it were, without tearing or injuring this nerve.

The method I use is to grasp the long process near its tip with fine ophthalmic forceps, and to push the whole incus further up into the



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attic. The tip is then lifted over the chorda tympani and the whole incus is lifted out.

On two occasions before using this delivery method I have accidentally torn the chorda tympani. This was followed by no demonstrable symptoms whatsoever—subjective or objective. Will physiologists kindly explain?

On the principle that no structure however trivial shall be eliminated if it can be preserved, this nerve should be protected if only as a test for the operator's delicate touch and to discourage slovenliness.

When the incus has been lifted out, the goal has been reached. The beautiful curve of the dome of the vestibule now leaps to the eye, above it the dark cave of the aditus. Below one sees the yellow pink facial canal reticulated with capillaries with its constant tiny vessel along the upper border. Below the canal, the articular surface of the capitulum of the stapes, and its crura descending into the fenestra ovalis and attached to the bluish looking footplate, are superlatively clear.

The stapedial tendon is still attached like a pennant to the capitulum of the stapes, and runs into the aperture of the eminentia pyramidalis.

On the cadaver the stapes is very loose—unless by chance the subject was an otosclerotic. Now has come the moment when we can test for stapedial fixation. This will be found to exist invariably.

Grasping the capitulum lightly and rocking it, will reveal no movement in the footplate. The crura may be fractured if the slightest force is used. If this happens, it is as well to snip through the stapedial tendon and discard the broken off portion—rather than leave it as a potential foreign body.

I have developed an important variation affecting Stages IV, V and VI which must be mentioned—but I do so with some hesitation.

In this alternative technique the surgeon is deprived of most of his valuable and beautiful landmarks. He must be able to visualize them and their exact relationship to the new restricted field.

### ALTERNATIVE TECHNIQUE.

An inverted U-shaped flap of meatal skin covering the outer attic wall is reflected down to its attachment to the drum at the sulcus tympanicus. The drum is not detached, but is left *in situ* and intact. A hole is drilled through the attic wall. The attic wall is cleared as described until the incus is revealed. In this variation, the articulation of the lenticular process with the capitulum of the stapes, is hidden by the drum. The lower ridge of the attic wall is carefully ground away from its attachment to the tympanic ring of the drum.

The blade of a tiny right angled knife is slipped down the posterior surface of the long process of the incus, to detach the lenticular process

# Fenestration of the Labyrinth

from the capitulum of the stapes, if this has not already come adrift during the manipulation

The incus is delivered and the dome of the vestibule lies exposed

I would urge my colleagues to follow the stages as described in the main part of this paper with the beautiful landmarks as their constant guide, and to attempt this variation when sufficient experience, skill and dexterity has been acquired. This variation may replace the standard procedure. The tympano meatal flap now becomes a simple meatal flap which presumably would possess greater viability.

Non-interference with the drum would keep down granulation forming tendencies—especially undesirable in the round window region

## STAGE VII *Enchondralization of the dome of the vestibule*

We are indebted to Shambaugh for the conception of enchondralization. He has shown that the enchondrium exhibits no tendencies for osteogenetic regeneration. Readers are referred to this brilliant investigator's publications on the subject.

The five layers of the vestibular dome are disposed in a curve. Thus by grinding down this cupola the outermost layers are removed most widely (Fig 2)

The layers are from without inwards

- 1 Mucous membrane
- 2 Periosteal layer of bone
- 3 Enchondral layer of bone
- 4 Endosteal layer of bone
- 5 Endosteum

In the anterior region of the dome a cistern of perilymph appears to exist, separating the saccule from the endosteum

This cistern is of great moment during fenestration procedure, in that it protects the membranous labyrinth during this manoeuvre

With either a flat ended, or spherical-headed diamond burr the entire dome is ground down flat to a level below the facial canal. The latter is kept constantly in view and the burrs are always directed away from this canal. Bone dust and debris are removed by suction irrigation every few seconds so that the field is immaculately clean. I use penicillin (100,000 units in 20 ccs) as the irrigating fluid and rarely is more than 20 ccs required.

Before grinding down the dome—and in fact, before any dental burr procedure is begun—it is wise to check that the tympano meatal flap is safely tucked away under the ledge of the tympanic plate and not likely to be fouled by the high speed burr. The fenestration site has crept forward during the last seventy years from the lateral semi-circular canal to the ampullary dome region (Lempert) and now to the anterior face of the dome itself (see Plate I). This latter site, rendered

accessible by the transtympanic approach, is the ultimate limit. It permits the largest possible fistula and by virtue of the cistern of perilymph it contains, appears also to be the safest. (Plate I).

In not one of my cases have I induced a labyrinthitis.

Vestibular disturbances of balance and orientation have been evanescent. All my patients have been able to walk about the ward unassisted on the third or fourth day after operation. In no case has hearing been destroyed. No freak manifestations such as disturbance of orientation for the source of sound have been observed.

It may be inferred therefore that the forward progress of the site is a vital step in this work. My site on the anterior face of the dome almost vertically above the stapes would seem to merit consideration.

The fenestration or enchondralization is not particularly difficult—or nerve racking. The facial nerve is seen throughout and most important of all the burr *never enters the labyrinthine cavity*. The burr end plays over the surface until a greyish area (endosteum) is seen—the eventual fistula. This greyish area is surrounded by a sago-like yellowish area—the *enchondrium*. A few droplets of perilymph can be seen seeping through it as well as through greyish area.

The flat grinding process over the surface is continued. The greyish area becomes larger. The endosteum with its attached membrane invariably come away together with a touch of the burr and a large fistula is created. Its edge is thin and the opening lies on the surface—not in a trough. The thickness of the periosteal layer ring is relatively far away.

MacEwan's classic "Growth of Bone" emphasizes that the osteoblasts in the periosteal layer of bone regenerate bone—not the periosteum or muco-periosteum—the latter in fact inhibit or limit this function. If this is accepted then Shambaugh's enchondralization assumes an enormous significance.

The mobile cartilaginous stopple of Lempert would seem superfluous. Indeed, if my information is correct, it has largely been abandoned in America.

I believe that a maximal opening into the labyrinth is the first defence against its early closure by osteogenesis. Such an opening can be made by the method described and without injury to the membranous labyrinth at the anterior location I have indicated.

After every vestige of bone dust has been removed by irrigation and mopping and the fistula is clean the final act commences.

## STAGE VIII. *Replacement of tympano-meatal flap to cover the fistula.*

The field is flooded with penicillin solution and the tympano-meatal flap assisted with the gentlest teasing, is floated off its anchorage from under the bony ledge of the tympanic plate. The excess penicillin

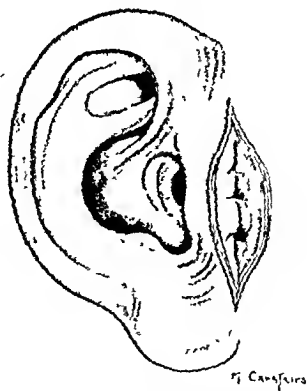


# PLATE 1

The forward progress of the fenestration site

- 1 The external semicircular canal
- 2 The ampullodome region (Lempert)
- 3 The anterior face of the dome (Popper)

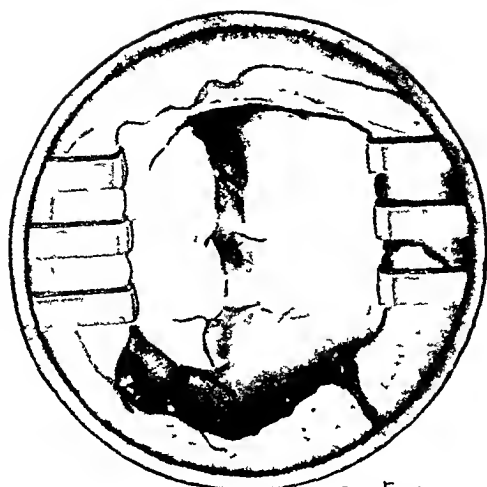
Note that the size attainable increases as the site moves forward  
A and B indicate, respectively the author's sites, as yet experimental for  
fenestration of the "Cochlear Vestibule", and Scala Tympani (Fenes-  
tration of the Labyrinth—Part I, *J Laryng and Otol*, Vol LXI  
No 1, January, 1946)



# PLATE 2 (Incision and stage 1 A)

Incision and

down to the latter's  
plate



M. C. Fair.

PLATE 3 (stage 1 B)

Detail of cartilage attachment to tympanic plate. The fascial covering of the temporo mandibular cleft is shown in front of the tympanic plate.



M. C. Fair.

PLATE 4 (stage 11 C)

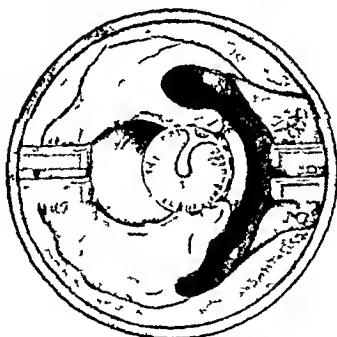
The cartilage is detached from the edge of the tympanic plate. The skin of the meatus and a portion of the drum are now visible.



M. Cars

PLATE 5 (stage II D)

The cartilage is retracted backward. The fascia and periosteum of the tympanic plate are retracted forward.



M. Cars

PLATE 6 (stage III E)

Removal of the tympanic plate. The entire drum is revealed square on. The tympanic plate need only be taken down to a point where the posterior half of the drum plus malleus and a strip of drum in front of it are exposed. This provides perfect and sufficient access to the attic for subsequent fenestration of the vestibular dome. If fenestration of the cochlear vestibule or scala tympani is contemplated the entire drum must be exposed as shown.

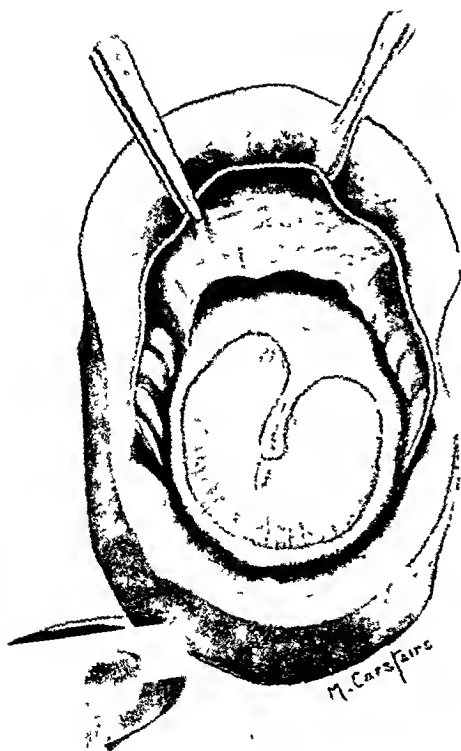


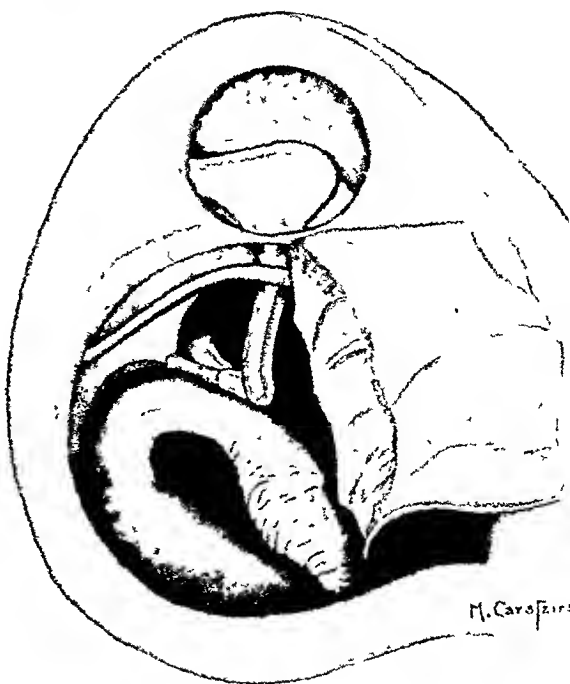
PLATE 7 (stage iv. F).

The tympano meatal flap as fashioned in the transtympanic approach. The meatal integument is reflected after infiltration. The tympanic plate gap lies antero-inferiorly.

PLATE 8 (stage iv. A.).

The tympano meatal flap together with the continuous posterior half of the drum are folded forward over the handle of the malleus. From below upwards are seen—  
the round window,  
the promontory,  
the eminentia

pyramidalis with the issuing tendon of the stapedium which is attached just below the capitulum of the stapes. The capitulum articulating with the lenticular process of the incus. The long process of the incus disappearing into the attic. The anterior crus and a small part of the posterior crus of the stapes. The chorda tympani crosses the long process of the incus, where the latter disappears into the attic.



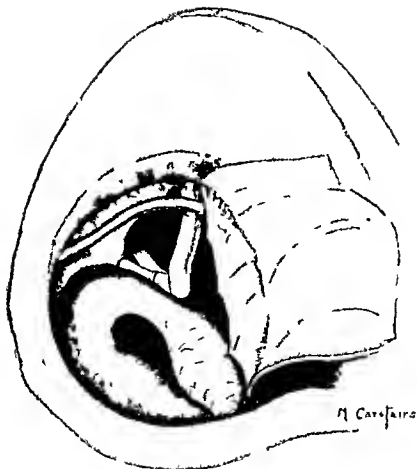


PLATE 9 (stage v H)

Same detail as Plate 8. A hole is drilled into the attic wall. Its centre is in line with the long process of the incus about two millimetres above the point where it disappears into the attic space. The body and short process of the incus are revealed and its articulation with the head of the malleus. The attic is now partly open.



PLATE 10 (stage v I)

The whole attic wall has been taken down. The entire incus is exposed. Above the attachment of its short process the dark cave of the aditus is seen. The anterior crus of the stapes is just visible between the neck of the malleus and the long process of the incus.



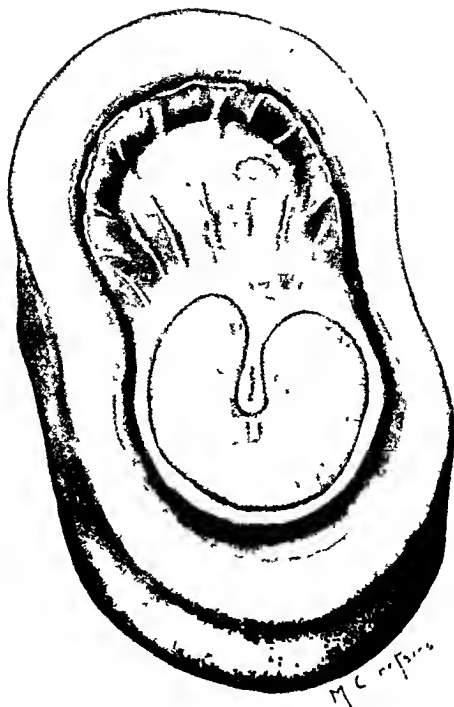


PLATE 15 (stage viii N)

The meatal skin has been closely adapted over the fistula

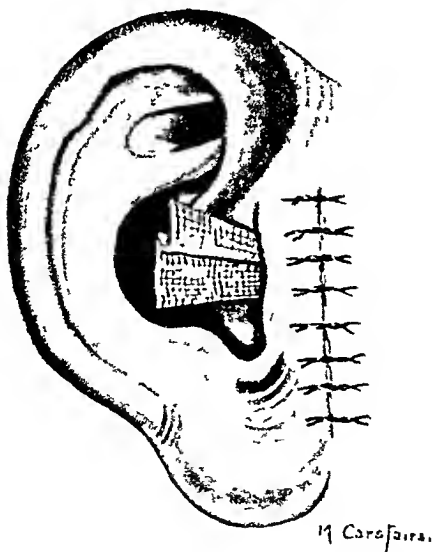


PLATE 16

The final sutures These are not knotted—a double loop suffices—there is no tension Vaseline gauze strip packs the meatus

## Fenestration of the Labyrinth

fluid is gently mopped away I use no suction at this stage for fear of finding my flap—or vital portions thereof—in the vacuum bottle

When the field has been dried, it will be found that the drum falls right back into its accustomed place—in fact everything in this operation falls into place—without tension or torsion

Lempert claims that Shrapnell's membrane covers the fistula With this Shambaugh disagrees It would need to be stretched considerably to reach the ampulla but certainly will not reach the anterior face of the dome

The meatal portion of the tympanic flap is now placed over the dome of the vestibule, its periosteal surface closely adapted to the fenestration Narrow ribbon gauze impregnated with vaseline and sulphanilamide powder is gently packed on top of it and into the meatal passage The other end of the strip (it should be about 18 inches long) is now pulled through the intact meatus from below

The object of placing skin over the bone is to provide a membranous covering for the newly created fistula

I believe Shambaugh holds the view that this protection is transient and that the real sealing off occurs when the mucous membrane lining the attic, and covering the dome grows over it One or other of the labyrinthine sacs, probably the saccule at this anterior site, rises in the perilymph to fuse with the under surface of this new mucous membrane

From my limited experience I would support this view

The incision is sutured with fine nylon, the stitches being about one-fifth of an inch apart The ribbon gauze is now packed from the external opening of the meatus The stitches are removed on the fifth day

The ribbon gauze is soaked twice daily with sterile liquid paraffin and removed on the seventh day It is advisable to repack should excessive granulations form These may block the deep part of the meatus

In favourable cases the patient hears unaccustomed sounds such as water splashing, bells and so on the same evening or the day following the operation, despite the packed meatus

Giddiness and spontaneous nystagmus usually disappear after the third day As a precaution every patient is given a full course of penicillin after the operation

So far I have not encountered the temporary labyrinthine blackout immediately following operation and described in the literature Presumably this is a serous labyrinthitis, possibly due to trauma

The minimal trauma of the transtympanic approach may account for its absence in my cases

It is my conviction that many surgeons who might have attempted this branch of surgery have been deterred by the somewhat strained

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explanation current as to why fenestration restores useful hearing.

By clinging to the Helmholtz theory, workers in this field have left us in an intellectual vacuum. We are asked to believe that the perilymph is now stimulated directly through the fistula by air-borne sound or that despite manipulation the replaced drum transmits sound impulses to the new fistula.

It seems imperative that a new orientation of thought on this subject is introduced. The explanation given is unsatisfying.

To operate in order to produce an effect for which we accept an untenable explanation challenges the intelligence. If the rationale of fenestration were more acceptable, far more recruits would be attracted into this field. Hearing improvement after fenestration can be accounted for on a hydrodynamic basis of reasoning.

### A HYDRODYNAMIC HYPOTHESIS TO ACCOUNT FOR HEARING IMPROVEMENT AFTER FENESTRATION IN OTOSCLEROSIS

1. Sound waves consist of positive and negative phases.
2. Fluid (perilymph) transmitting sound must therefore be capable of vibrating in register with these phases.
3. Fluid is incompressible and the labyrinth capsule is rigid.
4. A mobile normal stapes acts as an escape valve to allow for these displacements or vibrations of the perilymph, excited by sound impinging on the round window. The excursions of the stapes are in register with such displacements both for frequency and amplitude. These are passive movements of the stapedia footplate.
5. The normal stapes is able by muscular action to control and adjust the amplitude of the perilymph excursions thus protecting the organ of Corti from excessive and harmful stimulation. This is an involuntary protective function of the stapedia apparatus. An excessively loud sound may stimulate this reflex. It is assisted by relaxation of the tensor tympani and slackening of the drum which occur *pari passu* with contraction of the stapedius. Relaxation of the drum dampens the vibrations of the air in the middle ear and their transmission through the round window to the perilymph. An open Eustachian tube assists in the dissipation of sound—normally the Eustachian tube is closed.
6. Possibly another function of the stapes is to adjust the tension of the membrane covering the round window by hydraulic action. A specific tension will filter out or dampen unwanted frequencies and thus accentuate or focus on a particular sound spectrum. When listening to a full orchestra a musical ear has no difficulty in "picking out" the strings, the oboe or the English horn. Its counterpart is found in nature. A hunted animal despite the distracting sounds of the jungle—the song of birds, the hum of insects, the rustle of leaves—must focus

## Fenestration of the Labyrinth

) on one thing alone—the sound spectrum of the footpad of its relentless enemy

This function is then a voluntary, conscious, primitive, protective reflex. Variations in tension of the tympanic membrane may also assist in this focusing. A musical ear is alas an atavistic phenomenon!

This function in my opinion, is the first to disappear in Otosclerosis, but it may escape observation.

I have had three cases (all subsequently proved early otosclerotics) where the early complaint was not deafness but an inability to focus on individual instruments at concerts or on conversation at large gatherings. The hearing loss was small, well above the 30 decibel level.

In these cases one may deduce limitation of stapedial movement rather than fixation, the smaller passive excursions of the stapes excited by sound impinging on the round window were obviously adequate to accommodate the normal perilymph vibrations. These excursions are infinitesimal—the diameter of a molecule of hydrogen. Fluid being incompressible a positive phase at the round window (inward movement) must be accompanied by an outward movement of the stapes and *vice versa*.

In stapedial fixation this escape valve action is absent. The wave is therefore suppressed, dammed back, dampened and distorted and stimulates the spiral organ of Corti but feebly. It is not the organ of perception but the stimulus that is at fault.

If the entire labyrinth capsule plus perilymph is set to vibration, hearing is good—as is bone conduction in otosclerosis. Clearly a new escape valve must be created. Fenestration does precisely this and no more. It does not restore sound accommodation—that is irretrievably lost in any case in otosclerosis. The beautiful tympanic mechanism is impotent owing to stapedial fixation.

This hypothesis is based on the premises that sound transmission occurs through the round window.

The ossicles and muscles are a perfect organ of accommodation and protection. Why ascribe to them in addition the function of sound transmission? Such a duality of purpose would constitute a physiological curiosity and exception. This mechanism with its articulations is not designed for sound transmission but rather for its dispersal, diffusion and suppression.

The amplitude of sound waves activating the drum is reduced thirty times when it reaches the stapes, by the ossicular linkages. Its force however is not increased by this factor—the articulations are too loose as anyone who has removed an incus in the fenestration operation can verify.

The drum is the perfect receptor and catchment area for sound. Its tension can be varied—such gross movements occur without

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corresponding excursions of the stapes. These variations in tension assist in "focusing" for sound. The fact that the drum is attached to the ossicles has led to the belief that sound is transmitted *viâ* the ossicles to the oval window, whereas the loose linkages seem expressly designed to prevent this.

This seems a paradox until it is realized that mechanically this chain is badly adapted for such a purpose. Sound impinging on the drum sets the tympanic air into vibration. Some authorities claim that these intratympanic vibrations are amplified and focussed on the round window region.

Why should the drum then be even indirectly attached to the stapelial footplate? I believe this to be a protective measure. Excessive movements of the drum which may be injurious, when transmitted to the capitulum of the stapes, however attenuated by this time, excite an immediate reflex contraction of the stapedius and fixation of the stapes. The perilymph is instantly immobilized and the harmful excitation *viâ* the round window is dampened. In otosclerosis this fixation is a permanent feature.

This direct fixation reflex would be faster and more protective than, let us say, a reflex originating in the overstimulated organ of Corti.

To summarize, the tympanic membrane has three main functions

1. It is the most perfect receptor for sound.
2. It assists by variations of tension to "focus" for sound.
3. It protects the organ of Corti by
  - (a) an immediate tympano-stapelial reflex, and
  - (b) by relaxation, curtaining and dampening sound vibrations.

This is no attempt at a scientific exposition—rather a marshalling of random thoughts and the expression of a credo.

Discussion of hearing theories started in the sixteenth century. The argument still continues.

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I have endeavoured to give a detailed—if discursive account of the transtympanic approach and fenestration. I believe that fenestration has come to stay. Anyone disposed to ignore or belittle its possibilities should be reminded and sobered by considering the treatment that has been employed for deafness, otosclerotic or otherwise.

Eustachian catheterization.

Nasal operations—septum, sinuses.

Throat operations—tonsils, adenoids.

Other Operations

- (a) Creation of post-aural fistula of the mastoid.
- (b) Crude attempts at fenestration.
- (c) Extraction of the stapes.

## Fenestration of the Labyrinth

- (d) Exposure of the dura of the middle fossa to counteract an hypothetical venous stasis of the labyrinth
- (e) Ligature of the parathyroid gland

Vitamins

Vaccines, injections

Hormones

Electrical treatment—galvanism, faradism, diathermy

Pneumatic otomassage—to mobilize the ossicular chain

Drugs—their number is legion

This depressing list could be extended, I have no doubt. It is a testimony of despair. Those of us who have not subjected our deaf patients to any of these measures can fully understand the pressure exerted on otologists to do something. The least that can be claimed for them is that, with the exception of the operative procedures, they rarely did any harm. No wonder, therefore, that recent advances in labyrinthine surgery have created a tense situation which may have led to exaggerated claims.

The position with regard to otosclerosis can be stated with crystal clarity. All measures except fenestration have failed to cure, alleviate or arrest deafness. The hearing aid and fenestration alleviate deafness. Fenestration may, to some extent arrest the progress (Lempert).

If my colleagues approve of the transtympanic approach as an instrument which will make the operation available to all those afflicted, fenestration like the cataract operation may soon lose its sensational novelty.

It will and should be taken for granted as soon as it becomes a routine operation in every Department of Otology.

My experience comprises hundreds of cadaver dissections and a small number of operations on the living subject. These are too recent to warrant recording at this date.

The leap from the laboratory to the operating theatre is an agonizing moment. Its timing can be safely left to the judgment and conscience of the surgeon. It is my sincere hope that my paper will help to ameliorate this bridging.

The following spontaneous letter from a young woman may fittingly conclude this paper.

"It is very difficult for me to say just how much my hearing has improved through the fenestration operation but I do think that in view of all I can now hear I was very much deafer than I realized or would admit. In hospital just after the operation I began to notice lots of little things among which were footsteps in the passage outside all the bells ringing the telephone bell, the clock ticking and a wireless on the floor above me. Standing at the window of my ward on the third floor I could hear the trickle of water falling from a hosepipe in the garden. At my flat I realized for the first time that it was

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extremely noisy. I was kept awake with all the radios in the other flats. The voices of natives shouting from the yard of a nearby hotel were so clear that I thought at first they were in my flat. I have been in the flat for over a year and never once heard any radio than my own or any other sounds. I think the greatest benefit I have felt through my improved hearing is in attending to my business and in shopping. I have been able to do all this without any effort. Two sounds I have heard which have given me a great pleasure, are the softly falling raindrops and the singing of the birds here in Durban. The last I find particularly loud as I do any high note. The time signal on the radio for instance is often piercingly loud. I did not find the operation at all severe or painful and the dizziness soon passed away."

Labyrinthine surgery is precision work—an entirely new milieu and language for most of us. I am convinced that the transtympanic approach will help many aspirants to acquire its vocabulary and idiom. When this is accomplished and there is some prospect, however remote, of coping with the enormous number of otosclerotics, then like Prospero

"deeper than did ever plummet sound  
I'll drown my book."

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## ACKNOWLEDGEMENTS

Without the help of the University of the Witwatersrand, the Medical School and Johannesburg Hospital, my task would have been well nigh impossible.

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Professor H. H. Payne, Department of Physics  
Professor I. W. Brebner, Department of Surgery  
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I would like to express my appreciation to my artist, Miss M. Carstairs, for her great skill and inexhaustible patience and

Sir Ernest Oppenheimer for providing me with a new laboratory, and for his interest in the development of this work.

## CLINICAL RECORD

### FIBRO ANGIOMA OF THE RIGHT ALA NASI IN A BOY OF TWO YEARS

By C de W GIBB (Gloucester)

R D was seen on 12 9 46 on account of epistaxis, following a blow on his nose on 8 9 46. Anterior rhinoscopy did not reveal any abnormality. He was ordered nasal drops of ephedrine hydrochloride 0.75 in normal saline.

On 21 11 46 he again attended the outpatient department when the right nostril was filled by a tumour, dark red, bleeding on palpation sessile and attached to the inner surface of the ala nasi at the junction of the skin and mucous membrane.

On 22 11 46 a general anæsthetic was administered and the tumour was excised by means of two elliptical incisions around its base. There was smart bleeding which ceased when the edges were sutured.

The report of the biopsy was that the section showed normal skin and fibro angioma.

A fibro angioma, or bleeding polypus of the nasal septum is a rare condition and the occurrence of a similar tumour on the ala is still rarer. According to StClair Thomson it may occur between the ages of 6 and 70 but this one was in a child of two years.

The patient was last examined on 5 12 46 when the wound was found quite healed. There is not much in the literature on this condition, so that the record of a single case may be of interest.

Diseases of the Nose and Throat      Third Edition      Sir StClair Thomson



## SOCIETIES' PROCEEDINGS

### ROYAL SOCIETY OF MEDICINE—SECTION OF LARYNGOLOGY

May 3rd, 1946

*President*—G. EWART MARTIN, F.R.C.S.ED.

#### Discussion on Rhinology in the Mediterranean and African Areas

J. P. STEWART

I was responsible for the ear, nose and throat work in a British General Hospital at Teheran during 1943 and it was from that source that the material for this paper comes. The climatic and hygienic conditions are so intimately bound up with the infection of the paranasal sinuses, that I will briefly outline their main features. The southern half of Persia is mostly composed of arid barren desert. The summers are very hot with hardly a cloud visible in the sky and with a temperature of as much as 130° F., while the winters, though of short duration, are very cold with a temperature just above freezing point or even below zero. The rainfall is scanty even in winter. The annual fall in Teheran is 9.53 inches, so that the humidity is exceedingly low. For four months in the summer a constant dust-laden wind, which is called the Shamal, blows from the North-West. Whirlwinds wherein columns of dense dust and small stones are caught up, and going by the name of "dust devils" or "whirligigs", suddenly arise and tear through space drenching with dust everything and everybody in their erratic course. Sanitation is extremely rudimentary and much of the human excreta is deposited in open spaces. The sun bakes the excreta and in a very short space of time it disintegrates, becomes pulverized, and is blown about in the dust. There is no piped water from reservoirs and the water supply is obtained from open streams and if I describe the water supply of the capital city, Teheran, it will give an idea of the primitive conditions of such a supply. The main water supply is derived from the streams which run down from a mountain range some 10 miles distant and those streams often pass through some small villages in their course. Short of the city these streams are directed into open artificial channels and then led into the city to be diverted into large gutters with an earth or cement base which run down the principal streets. One does not need a great stretch of imagination to visualize the indignities to which this water supply is subjected during its course through the city. Swimming pools were filled from the open supply but the water was taken off from as far out from the city as possible and they were, when under military supervision, heavily chlorinated. Despite the heavy chlorination many cases of paranasal sinus infection arose from these swimming pools as no doubt the heat of the water and the exceptional number of people using the pool contributed in no small measure to the infectivity obtaining in it. In the field, water was scarce and the best of it was taken for drinking purposes so that practically any other

## Royal Society of Medicine

source of supply was used for washing. The British Tommy when washing invariably threw handfuls of water on to his face some of which would enter the nasal cavities and it was quite a common practice for him to sniff water into the nose and then expectorate it as this moistened his dry nose and washed the dust and grit out of it. It can readily be appreciated that infection of the nasal cavities might thus take place by the introduction of infected water.

Locomotion was by motor transport and a column on the move was shrouded in a thick dust pall which coated the individual from head to foot and irritated the upper air passages beyond measure, and one's expectoration was black with grit and dust.

During the ten months 896 ear, nose and throat cases passed through my Department and 303 suffered from an affection of the external or internal nose. 154 (51 per cent) of those cases were due to an infection of one or other of the paranasal sinuses. The maxillary air sinuses were affected either uni- or bilaterally in 106 cases, the frontal sinuses similarly in 8 cases and a combination of these two sinuses in 8 cases, the ethmoid cells in 30 cases and a pansinusitis occurred in 2 cases. A preliminary X ray examination of the sinuses was made in every case, and a proof puncture was performed to confirm the radiological findings in cases of suspected maxillary antrum infection. In 40 cases the returning fluid from the antral wash out was clear or had shreds of mucus in it but there was a varying amount of resistance to the irrigating fluid thus demonstrating a swollen antral mucosal lining. A further 21 cases yielded mucopus while in 54 cases frank pus was washed out, generally in copious quantity.

This high incidence of every second case suffering from nasal sinus disease was mainly due to climatic and hygienic factors. The intense heat of very low humidity dried up the natural secretions of the nasal mucosa causing the mucous membrane to become congested, dry and glazed. Infected dust was then inhaled, which impregnated this irritable membrane thus opening up the pathways of infection. When infection became established and an exudate formed, it too was dried up and formed a cake or crust which retarded further drainage from the deeper structures and in fact sealed them off. Much the same sequence of events was produced by infection which was water borne though dust was by far the most frequent infecting agent. A number of cases gave a history of a previous attack of nasal sinusitis which, though it had cleared up, recurred readily under the conditions described.

The treatment of those cases of nasal sinus disease which took place in the pre penicillin era, did not differ from that employed elsewhere. There was little contra indication to operation but one had to be on the outlook for signs of heatstroke and heat exhaustion especially if there was much loss of blood, post anaesthetic vomiting, or indeed any marked dehydration of the tissues. If the patient had suffered from a previous attack of malaria, operation often precipitated another attack giving rise to a high temperature which was rather worrying until the cause of it was ascertained, therefore a blood slide was taken as a routine from all cases which ran a temperature following operation. 42 cases were operated upon—31 radical antrum operations, 1 intranasal antrum drainage, 4 external frontal sinus, 1 intranasal frontal sinus drainage and 5 ethmoidectomies were performed.

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The post-operative results were rather disappointing but I believe that if penicillin had been available those results would have been much more satisfactory. The sulphonamides did not prove of great value in promoting healing. Recovery was retarded mainly because of a constant reinfection of the raw areas. The operation cavities continued to suppurate for a long time so that it became necessary to advise, in the majority of cases, evacuation to a more equable climate.

In the course of time our experience taught us to operate less and less on this type of infection and any marked case of sinusitis was at once recommended for evacuation.

R. B. LUMSDEN (*Abridged*): *Climate*.—Except for a narrow belt along the Mediterranean shore, where 8 to 12 in. of rain falls in the winter months only, Egypt is almost rainless. At Alexandria, the mean maximum temperature is 99° F.; while 130 miles inland at Cairo, where the proximity of the desert begins to be felt, it is 110° F. At Cairo the mean relative humidity in summer is about 45 per cent. and in winter about 70 per cent. (*Encycl. Brit.*). There are periods, however, especially in spring, but also in autumn and summer, when this is much lower. These periods occur during the "khamsin"—a dusty, sand-laden wind which blows off the desert for several days on end, during which the temperature is high and the air extremely dry. These "khamsins" also occur in Palestine, where hot, dry summers are experienced, but where, unlike Egypt, there is a heavy winter rainfall.

*Sinusitis*.—During the year 1944, the total number of ear, nose and throat cases seen throughout the Command was 27,816, of which 6,105 (22 per cent.) were nasal cases. Of these, 834 (13·7 per cent.) were *admitted to hospital* on account of sinusitis; 347 (5·7 per cent.) being chronic and 487 (8 per cent.) acute (*see Table*). Unfortunately consolidated records do not provide figures

## MIDDLE EAST FORCE, 1944 (ALL HOSPITALS).

Total number of ear, nose and throat out-patients	27,816	
Total number of nasal cases .. .. .	15,091	54·3%
Total number of <i>nasal</i> cases .. .. .	6,105	22%
Total number of throat cases (excluding acute tonsillitis) .. .. .	3,337	12%
Total number of laryngeal cases .. .. .	656	2·3%
Negative examinations .. .. .	2,627	9·4%
Cases <i>admitted to hospital</i> on account of sinusitis—	834	13·7% of all nasal cases
(a) Chronic .. .. .	347	5·7% of all nasal cases
(b) Acute .. .. .	487	8% of all nasal cases

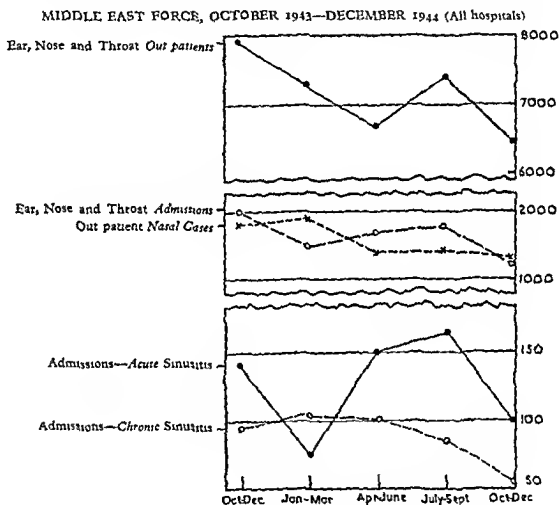
relating to individual sinuses, nor do they afford any detailed statistical information concerning out-patient cases. Collins (1943), in Cairo, found that 20·3 per cent. of his total out-patients and 66·8 per cent. of nasal cases suffered from sinus infection, but these figures appear to be high for the Middle East as a whole. Many of my own figures were unfortunately lost in transit.

Concerning *treatment*, Collins (1943) found that 74 per cent. of his sinus cases yielded to conservative measures, which included repeated proof puncture. There was general agreement with his plea for conservative methods. As after all nasal operations, convalescence was slower than at home and final operative results were, on the whole, less satisfactory. It appears that the

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penalties of interference with the nasal mucous membrane are infinitely greater in a hot, dry climate

*Seasonal incidence* At the top of the chart are shown the quarterly figures of (1) all ear, nose and throat out-patients, (2) out-patient nasal cases, and (3) ear, nose and throat hospital admissions throughout the Command, from October 1943 to December 1944. The general downward trends are an indication of a general reduction in the population. In the lower half of the chart the interrupted line shows the number of admissions to hospital on account of *chronic* sinusitis, and it will be observed that the seasonal incidence was fairly constant. The upper line relates to admissions on account of *acute* sinusitis and shows an appreciable summer rise. A similar incidence was observed in respect of less severe cases treated as out-patients.



Undoubtedly many cases of sinusitis were related to swimming in fresh water pools (Collins, 1943, Lumsden, 1945), and resolution was generally slow. In South Iraq, on the other hand, Reeves (1943) comments on the small number of cases of acute sinusitis admitted during the dusty summer months. We found that the large majority occurred in the cold weather. It is to be noted that 48 per cent of his patients were Indians.

There was general agreement with Collins (1943) concerning the frequency of frontal headache associated with sinus tenderness, and redness and frequently dryness of the mucosa of the middle turbinate. This condition occurs most frequently during the hot, dusty "khamsin" winds already mentioned and

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is most common in Egypt, where "khamshins" are associated with a much dustier atmosphere. As Collins has pointed out, while an allergic factor may be present, clinically it does not resemble vasomotor rhinitis. The diagnosis of acute frontal sinusitis was generally applied to these cases, but there would appear to be some justification for regarding the condition as that of "vacuum" sinus headache. Colleagues who served in different parts of the Middle East corroborate the opinion that this condition seldom occurs near the sea and Daggett informs me that he did not encounter such cases in Malta, where the climate remains humid throughout the year.

A series of laboratory experiments on rabbits has been carried out by Rosedale (1944) concerning effects of temperature and humidity on sinusitis. He found that a relatively cool and dry atmosphere was the most beneficial, while a hot and relatively dry atmosphere was the most harmful.

Though in several respects not strictly comparable, reports in recent literature suggest that the incidence of sinusitis is considerably higher in Egypt (Collins, 1943) than at home (Birrell, 1944), and that it is slightly higher at home than in North Africa (Birrell, 1944) and Iraq (Reeves, 1943).

*Deviations of the septum:* It was found, as in sinusitis, that patients who gave a history of mild symptoms of nasal obstruction at home frequently sought advice because these symptoms had become more marked and persistent after going abroad.

*Atrophic rhinitis* was encountered infrequently. Severe cases presumably were not sent overseas. The cases seen gave a history of relatively mild symptoms at home, but found summer conditions, especially in desert districts, quite intolerable and these had to be sent home.

In spite of the frequency and severity of *diphtheritic infections*—both faucial and cutaneous—nasal infection was very rarely encountered.

*Leprosy* was never seen in European Service personnel.

*Nasal allergy.*—True *pollen allergy* was judged to be comparatively uncommon and symptoms are of short duration. A number of people were encountered who suffered from hay fever at home, but did not experience seasonal symptoms in these regions. On the other hand, an appreciable proportion of the forces experienced mild symptoms of perennial *vasomotor rhinitis*. One frequently heard people commenting on their nasal stiffness and watery discharge, though only a relatively small proportion suffered enough inconvenience or discomfort to warrant seeking advice. Symptoms were accentuated during "khamshins" and showed no appreciable tendency to diminish, even after long periods of residence, while, by way of contrast, it was observed that otitis externa took a much heavier toll of fresh arrivals than of those who were thoroughly acclimatized. Many of the severer cases gave a history of suffering from hay fever or mild perennial symptoms at home and these people were not prone to develop the dry nose with so-called "vacuum" sinus headache, so that an excessively moist nose affords a compensatory safeguard against this condition. The absence of this condition among African native troops was noted, though it occurs among the Egyptian population.

Finally, some advice concerning patients who propose to proceed to this part of the world:

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(1) Sufferers from *nasal affections* need not be dissuaded from spending the winter in Egypt. On the other hand, they should be discouraged from believing that their condition will benefit materially therefrom.

(2) Sufferers from chronic or recurrent acute sinusitis should be advised against spending the spring, summer or autumn months in any of the Middle East countries.

(3) Persons afflicted with true *pollen allergy* may escape the acute discomfort of the hay fever season at home, but they cannot confidently expect to enjoy complete freedom from all nasal symptoms.

(4) *Vasomotor rhinitis* is unlikely to be relieved and might be aggravated.

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REEVES, B, 1943 *J Roy Army med Cps* lxxxi, 78  
ROSEDALE, R S, 1944, *Ann Otol Rhin Laryng*, liii, 144

WILLIAM MCKENZIE I was posted to Cairo from India in June, 1943. The war by that time had left Cairo behind, and the nearest battle front was 1,000 miles away. The only active combatants in my area were the few pilots who undertook the exceedingly dangerous duties of photographic reconnaissance. I do not think my work differed much from work in peacetime in the Cairo area, if allowances are made for the greater likelihood of the spread of infection in barracks. There were of course large numbers of the Royal Air Force in the area, how many I never found out, as this was secret information, but I should guess I served upwards of 25,000. For the most part these men were engaged in clerical work, or in maintenance of supplies to the various theatres of war.

The contrast between my Service patients and the few natives I saw was striking. I think a laryngologist requires an educated patient, if he is to give of his best, but with the natives I saw it was obvious that no amount of explanation or of reason would be of use. They required a quick and dramatic form of treatment, and a promise of absolute cure.

In the last few months of my appointment I went to Palestine once a week to visit the R A F Hospital near Tel Aviv. It is suggestive for the future that I began my clinic there at 9.30 in the morning, having already travelled 250 miles by air from Cairo. I returned to Cairo the same evening, having seen between 20 and 30 out patients, and this I did regularly each week.

Cairo was a surprise to me, as I think it is to most Englishmen. It is an ancient city which has never been sacked nor has it been destroyed by fire. The present city certainly dates back to the Romans and the streets are now some 40 ft above the floor level of the old Coptic churches. There is no rain and the dust cloud is continuous so much so that the sun never tans the skin in the city and the suburbs. Most of my patients were quartered in or near,

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the city and I am sure the atmosphere was a cause of the infections of the nose and throat.

The desert was healthier and I was often told that symptoms of sinus infection were less troublesome there. The weather too had much to do with the number of cases seen, but it is easier to be sure of the weather as a factor, as infections varied so obviously with the seasons. The Nile rises in mid-June and it is at this time that cases of sinus infection are seen in greatest numbers.

In Cairo antral infection rises steadily to a peak in July, when we had to set aside two mornings for antral lavage alone. I will describe results of treatment later, but by the expression antral infection, I include all cases where the infection of the antrum is the controlling factor, although other sinuses may be involved.

I think antral infections are more common in the Services generally than they are amongst civilians and a possible reason is the fact that a number of people live and work in close contact. In Cairo, at all events, the outdoor bathing pools were responsible for a number of sinus infections. Everyone bathed in Cairo and bathing is possible for nine months in the year. The pools were used every day and in most cases all that could be done was to empty them, and chlorinate them overnight. They were, in fact, only empty for an hour or two during the night. So many patients came with a history which began after bathing, that it was obvious that there was some relation, but while it was clear that the swimming pools made the infection worse, it was still possible that the infection had already been planted in the nose.

These cases were admitted with the usual signs of an acute sinusitis. If they improved with rest and inhalations I did not wash the antrum out, but this was often necessary. If the infection was overcome in this way, there was no difficulty, but the chief problem was the subacute or recent case which did not improve.

However, an antral infection which has not improved with lavage and rest is not enough to justify repatriation, and it was my experience that transfer to another Middle East climate, such as Palestine, did little good. I think many would have recovered in England, but I could not send them home for this reason.

This will explain, I hope, the number of operations for acute and subacute sinusitis. Where the history was longer than six months, and there was no improvement after the antrum had been washed out six times, an antrostomy was performed. The results were fairly good; certainly equal to what I would expect in England.

It is curious that recovery from operation is as good in Cairo as it is in England, even in hot weather. There were few complications: the alveolar incision in a Caldwell-Luc antrostomy perhaps became more readily infected, and certainly closed more slowly, sometimes taking three months. The worst complication I saw was infection of the fat of the cheek following a Caldwell-Luc antrostomy, and subsequent slow separation of the slough. There was one death, in an officer who had a recent infection, and who was recommended for operation because he held a key position in the Middle East. He developed an acute pancreatitis, and later died from an empyema.

Two interesting cases were two young Australians, both referred with

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bronchiectasis and antral infection. Both these men had only been a few months in the Middle East, and had never had either sinus or chest symptoms before. After this, I looked carefully for evidence of bronchiectasis as a complication of sinus infection in Cairo, but with no result.

If antral infection is common in Cairo, there is one condition which is rare compared with civilian life, and that is vasomotor rhinitis or vagotonia. I can say definitely that this condition was seldom seen compared with the incidence in a London clinic to-day.

Table I gives the numbers of cases of antral infection seen in Cairo, and the result of treatment.

Operation was of course only undertaken after failure of lavage, and in the acute and recent cases both lavage and operation were avoided.

A comparison with infections in Palestine is given in Table II. The number of patients is less altogether, but the danger from bathing was less, as it was seabathing for the most part. There is an increase, however, compared with England, and this I think must be due to the climate of the Mediterranean area generally.

TABLE I  
CAIRO No 5 R A F HOSPITAL  
July-December 1943

Out-patients	869	Chronic
Acute sinusitis	85	Improvement
Chronic sinusitis	118	Rest and inhalation
		Lavage
		Operation
Results of treatment of antral infection		No improvement
Acute and subacute		Lavage
Improvement		Operation
Rest and inhalation	20	Secondary to swimming
Lavage	34	Antral infection of dental origin
Operation	10	Antral infection following g
No improvement		wound
Lavage	11	Allergic rhinitis
Operation	1	Allergic rhinitis worse in Cairo

TABLE II  
PALESTINE No 3 R A F HOSPITAL  
June-December 1944

Out patients	388	Chronic
Infection of nasal sinuses	76	Improved
Antral infection		Lavage
Acute and Subacute		Operation
Improved		Not improved
Lavage	19	Lavage
Operation	3	Operation
Not improved		Secondary to swimming
Lavage	2	Antral infection of dental origin
Operation	1	Allergic rhinitis

R SCOTT STEVENSON spoke of his experience on Cyprus where he a large amount of vasomotor rhinitis in people coming from France who encountered a completely new flora with new pollen. Over a hundred W R N S were working there, many in the trenches. From one side of the Rock to the other, and among the rocks, trouble was found, owing to the prevalence of limes.



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desensitization by Francis's method of the irritable nasal mucosa, which in most of the cases gave a great deal of relief. One girl never left off sneezing as long as she was working in the tunnel, and her trouble in this respect was so severe that she was actually going to be sent back to England because of persistent rhinitis; repeated treatment with the dull-red galvano-cautery, however, enabled her to stay on at Gibraltar. The climate of Gibraltar was good, and during the two years he was there no rain fell from May until late September, but during the actual rainy season in March and April the fall was heavy; the annual rainfall was from 25 to 35 inches. There was a double water supply on Gibraltar, fresh and salt, the use of fresh water being much restricted. All their bathing was in the sea, and he did not believe that sea-bathing made sinusitis any worse; he had found many more cases of sinusitis when stationed in the West of Scotland, where it was very wet; he could remember seeing ten or a dozen cases in his out-patient clinic there in a single day, but on Gibraltar, although sinusitis was seen, it was not nearly so common. When operation was necessary in chronic maxillary sinusitis, he nowadays invariably carried out a Caldwell-Luc operation, and his experience was that this operation was very effective; his routine method was first to carry out lavage on three occasions, and if the condition did not clear up then a Caldwell-Luc was done.

W. I. DAGGETT said that in the Central Mediterranean area where he was stationed the incidence of sinusitis was extremely low. During a period of two years and three months when British troops numbered about 24,000, he operated upon only three cases; on one of these cases he carried out a Caldwell-Luc operation. All the bathing was in the sea. One very common nasal complaint which he found in the garrison of Malta, where the circumstances were very trying, was functional nasal catarrh. A great number of the cases showed a mild anxiety state, and amongst such patients it was extremely common to get patients who came along complaining that they were being "*poisoned*" by the catarrh they were swallowing.

C. A. HUTCHINSON said that he was interested in the apparent association of a state of high relative humidity with the inverse occurrence of chronic sinusitis. He had spent two years in West Africa where there was a very high temperature and an extremely high relative humidity, but chronic sinusitis in particular—and any form of sinusitis for that matter—was practically non-existent there, and the main ear, nose and throat work consisted of various forms of nasal and aural myiasis. He had also spent four years in Central India, where there was an extremely high temperature—for about six weeks of the year the shade temperature was  $116^{\circ}$ —and here again there was a fairly high relative humidity, except in the "hot weather", when it was very dusty. In that part of the world there was a certain amount of sinusitis, particularly of the chronic type, but its incidence was not unduly high. In Northern India and on the Frontier, where he had spent more than four years, one had again extremely fierce heat but absolute dryness throughout a long "hot weather", with a great prevalence of a dusty wind comparable to the "khamsin" mentioned by previous speakers. There he had found a very high incidence of chronic sinusitis, though during a brief "cold weather" a large number of acute antra were seen. The site of chronic sinusitis found

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in Northern India was mainly frontal and ethmoidal, necessitating operative intervention—and cases had done well. It seemed to him that there must be some inverse relation therefore between the degree of relative humidity and the amount of chronic sinus infection to be found in a particular area.

J ANGELL JAMES said that his experience in the Middle East extended only over five months, as the greater part of his time overseas was spent in Italy and North Africa. In Cairo, his experience was very much the same as that brought forward by Mr Lumsden, except in so far as the seasonal incidence of acute sinusitis was concerned. He arrived there at the beginning of August which was regarded as the peak period for sinus trouble. A moderate number of cases were seen during that month, and the numbers fell during September and October, but in November they increased again and during December there was an epidemic, with many more cases than were seen in the summer.

With regard to the treatment of these cases they were fortunate in having ample supplies of penicillin. Many of the cases cleared up with hospitalization and treatment with penicillin and sulphonamides, and ultra-short wave therapy. The symptoms disappeared within a week, and the cases were seen again at the end of a fortnight and at the end of three weeks skiagrams were taken. Not more than 10 per cent failed to respond. (Local chemotherapy was used for those that failed to clear up completely with systemic treatment.) He himself had suffered from a severe attack, but the active phase lasted only four days, and on the sixth he started work again. In two weeks his sinus skiagrams were again clear.

It was considered that cases showing gross ethmoiditis were not suitable for operation in hot and dry climates, so that with few exceptions only antral operations were performed, and there he always used the Caldwell Luc method, because his experience was that the cases which did not respond to local chemotherapy invariably had polypi or gross thickening of the mucosa in the antrum. Mr McKenzie had mentioned the relatively small number of cases of allergic rhinitis seen in Egypt, at home he thought that 10 per cent of all out-patients had some allergic signs, but in Egypt not more than 2 per cent showed them.

J A KILPATRICK said that his experiences were very similar to those of Mr Lumsden. The water in Egypt was definitely over chlorinated, resulting in his own case in a stinging of the eyes which went on to conjunctivitis, wholly due, in his opinion, to the amount of chlorine in the water. He felt that probably the additional chlorine had an effect on the nasal mucosa, giving any organisms present an easier task. He had gone on to Malta from Egypt, and there he had an acute frontal sinusitis and recovered only after five weeks.

B S CARTER said that he had been very much impressed in the Middle East, and even more so in Madagascar, with the high incidence of sinusitis in the South African troops. He was even more surprised to find how many of these South African troops had previously had radical surgery. The Caldwell Luc operation seemed to have been carried out in South Africa on a much more extensive scale than in this country. As a rule, these cases seemed to do badly, but how much was due to a functional element he did not know. In Madagascar there seemed a tendency to a great deal of functional

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complaint. People came along saying that their sinuses were unsatisfactory and on examination one felt that further surgery was contra-indicated; they did not seem to improve on ordinary conservative measures, and a number had to be invalided back to South Africa. His own experience of the climate of South Africa was just a passing one, but he supposed that it was rather drier than in England, and it did appear to him that the South Africans were more prone to the symptoms of chronic sinusitis.

T. B. JOBSON said that he recalled a large number of such cases being in the hospital at Cairo in the war of 1914-18, and he remembered receiving a chit from headquarters asking him "if his operations were really necessary". It appeared that a slight deviation of the septum which in this country caused no particular trouble changed its character in Egypt, and became the cause of a good deal of complaint. At all events he had a large number of men who had not a very marked deviation who in Egypt made the complaint of inability to breathe properly.

THE PRESIDENT said that one interesting statement was that sinus infection was more common in areas where living quarters were close, suggesting that sinus trouble was infectious. Possibly it was, but one wondered what happened in slum quarters where living conditions were worse than in crowded camps.

J. ANGELL JAMES, in reply to a question by the President, said that the cases he had mentioned were diagnosed on clinical and radiological signs and followed up radiologically afterwards. (Swabs were taken before embarking on penicillin treatment.) Proof puncture was not performed except in cases that failed to respond, because he did not consider it advisable to puncture sinuses during the early stages of acute sinusitis.

R. B. LUMSDEN agreed that little or no trouble was experienced from sea bathing and that chlorination of fresh water swimming pools might be a precipitating cause of sinus infection. In a warm climate, people indulge in swimming while suffering from colds; this might aggravate an infection already present in the nose. He himself suffered from hay fever at home, but except for one week, while living with orange groves around him, he never suffered from hay fever in the Middle East. The operation figures he had given were the collective figures of all the surgeons in the Command.

J. P. STEWART, in reply to a question, said that it was quite impossible to make any comparison between the intra- and extranasal operations on the antrum in this series because only one intranasal drainage was carried out as against 31 extranasal operations. He was in complete agreement with Dr. Scott Stevenson's remarks as to the positive value of the Caldwell-Luc operation.

WILLIAM MCKENZIE said that he had not found the number of septum operations to be higher in Cairo than in England, and he had never performed a submucous resection in candidates for air crew, in the absence of symptoms on the ground.

## REVIEW OF BOOK

*A History of Medicine* DOUGLAS GUTHRIE M.D., F.R.C.S.E., F.R.S.E.  
72 Plates Thomas Nelson & Sons, Ltd Price 30s

MANY have written what may be called sectional histories of medicine but this work is highly ambitious, covering the whole range of the history of medicine from Egypt to Osler. The result fully justifies these ambitions and the author has produced an admirably balanced and comprehensive history.

Any history of medicine cannot but consist largely in a recital of the names of those who have advanced medicine in their particular lines. In this work there is no lack of names but the author has infused life into his recital and the whole book can be read with much interest, indeed almost like a romance. He enlivens the story by many little human touches and numerous interesting illustrations.

He points out that disease is found in the oldest known skeletons, e.g. that of a dinosaur, millions of years old.

Sketches of medicine, Egyptian, Indian, Assyrian, Jewish, Chinese are given, it is of interest that in China, cretins were fed on the thyroids of sheep and that a surgeon about 200 A.D. practised excision of the spleen and that great attention was paid to the pulse, two hundred varieties being recognized.

Then comes Greek medicine with Hippocrates, Roman, chiefly of interest for Hygiene and the building of Hospitals. St Bartholomew's Hospital was founded by Rahere.

Mediæval medicine was mainly responsible for the revival of anatomy and surgery, among the great names is that of Galen who made many *ex cathedra* statements and was so highly regarded that any contradicting of his views was considered heretical, indeed Galen must have crippled progress for a thousand years. The following verse shows that clinical teaching was practised in Rome.

I'm ill I send for Symmachus he's here,  
A hundred students following in the rear—  
All paw my chest, with hands as cold as snow,  
I had no fever, but I have it now.

One man, Guy de Chauliac, 1300-67, deserves special mention, not only was he an originally-minded surgeon, but he instituted a practical comfort for patients that survives to this day—a rope above the bed to facilitate changes in position.

Tradition was at last broken down by men who insisted on thinking for themselves and foremost was Harvey who laid the foundations of modern medicine, he was followed by many famous men in the 17th and 18th centuries.

The author points out that there always have been centres of medical teaching and learning and mentions how they have moved from country to country depending no doubt on the teachers in charge. First came Cos,

## Review of Book

later Salerno, Montpellier, Padua, Leyden and then Edinburgh whose school was founded by Sir J. Pringle who had studied at Leyden. Pringle it was who when an army surgeon, suggested to the French commander that Hospitals should be considered sanctuaries, so initiating the Red Cross.

Edinburgh remained the leading medical centre for many years and the author, though a Scot, supports this view convincingly. With the era of Pasteur and Lister history of medicine speeds up tremendously so that the historian's task becomes much more difficult but Dr. Guthrie is equal to it.

It is impossible to single out individuals and their work but a few interesting facts and sayings may be quoted. In 1707, Sir J. Floyer invented "the Physician's pulse watch" which ran for one minute only. The clinical thermometer was scarcely used till the end of the 18th century. About the same time percussion was practised by Auenbrugger the son of an innkeeper who had been used to percussing his father's wine casks to ascertain the level of the contents.

In 1816, Laënnec invented the stethoscope, a wooden cylinder a foot long and one and a half inches in diameter and advocated its use in place of the old direct method which "was not only ineffective but inconvenient, indelicate and in hospitals even disgusting".

Lastly, two sayings by physicians, Gull's first, "However clever you are, you are sure to overlook Phthisis, Syphilis and Itch". Wilks made a remark which sounds very modern in these days of labour shortage! "Nursing sometimes a trade, sometimes a profession, ought to be a religion."

One statement about Laryngology must be corrected. Garcia is credited with the invention of the laryngeal mirror in 1855; actually Dr. Benjamin Guy Babington, a physician at Guy's Hospital demonstrated his "glottiscope" at a meeting of the Hunterian Society in 1828.

The vast number of references indicates in some degree the author's industry which fills one with admiration. An excellent and most readable History.

# The Journal of Laryngology and Otology

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*September 1946*

## WHAT CAN WE DEDUCE FROM QUANTITATIVE ESTIMATIONS OF BONE CONDUCTION?

By A. TUMARKIN (Liverpool)

### Introduction

IN a recent discussion at the Otological section of the Royal Society of Medicine, it was generally agreed that audiometer estimations of bone conduction were unreliable and misleading. Similar opinions have been expressed in America, especially by those surgeons who are performing the fenestration operation. There is a tendency to revert to the use of tuning forks in the estimation and diagnosis of deafness. In the writer's opinion this is an unfortunate tendency. Audiometer tests as performed with modern machines can give more information than any tuning fork tests. Nevertheless the quantitative audiometry of bone conduction is inaccurate owing to a fundamental difference between the view point of the otologist and that of the physicist or manufacturer. In the present article, I discuss that difference and indicate the means for resolving it.

### THE CLASSICAL ASSUMPTIONS

Let us assume that bone conduction is never diminished by any abnormalities in the conducting tissues, so that provided an individual's inner ear is normal his BC will be normal however diseased his skull or middle-ear structure may be. This assumption is, of course, not valid, but starting from it we shall arrive at a simple hypothesis and we may then re-introduce the necessary variables in order to approximate to

the actual conditions. It follows that any diminution in B.C. must be attributed to disease of the inner ear i.e. perceptive deafness. Furthermore hearing loss by air conduction represents the total deafness due to the conductive loss plus the perceptive loss. If the B.C. in such a case is normal, then the disability is entirely conductive. If B.C. is reduced then the conductive deafness is estimated by subtracting the B.C. loss from the total loss.

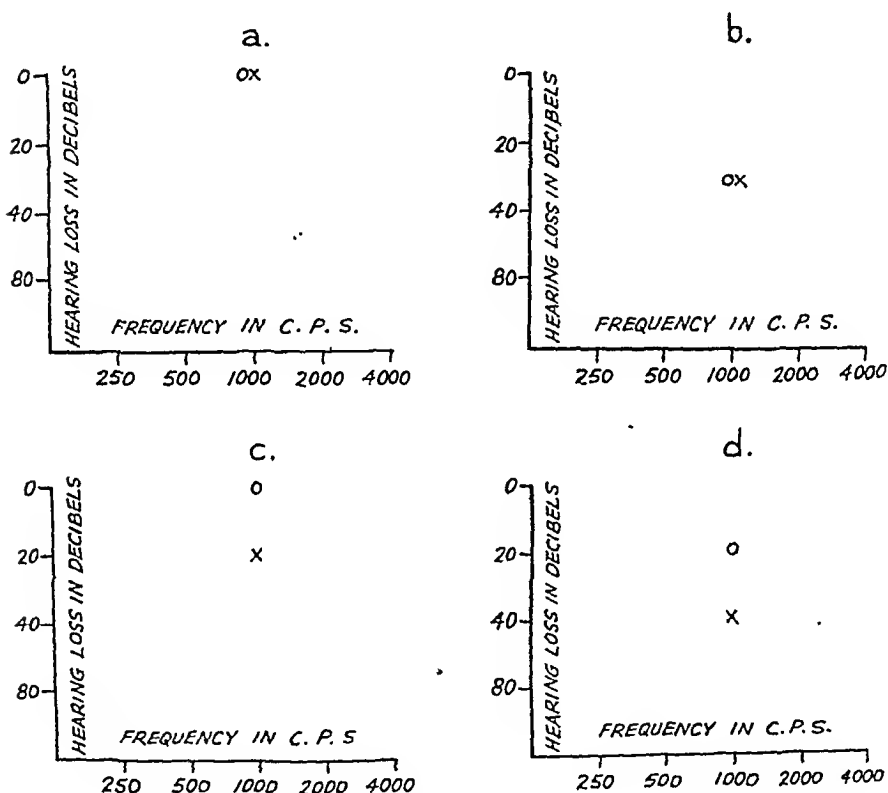


FIG. 1.

HYPOTHETICAL AUDIOGRAMS. Based on Classical Theory.

(a) Normal ear. (b) Pure perceptive deafness of 30 d.b. (c) Pure conductive deafness of 20 d.b. (d) Mixed deafness 20 d.b. perceptive plus 20 d.b. conductive.

X—Air Conduction. O—Bone Conduction.

Only figures for 1000 c.p.s. are shown.

In Fig. 1 the findings (on this hypothesis) are shown for the auditory acuity at 1000 c.p.s. of (a) a normal ear, (b) a pure perceptive deafness of 30 db., (c) a pure conductive deafness of 20 db. and (d) a mixed deafness of 40 db. made up of a 20 db. impairment in the inner ear and 20 db. in the conducting mechanism.

# Quantitative Estimations of Bone Conduction

This is how we should wish our tests to work. It is roughly the point of view developed by Fowler before the American Otological Society on May 27th, 1935. If that indeed was the way in which the ear worked, we should have no difficulty in using the audiometer in the diagnosis and estimation of deafness.

Unfortunately, matters are by no means so simple and it is high time that the more obvious fallacies in the procedure were analysed.

## THE THRESHOLD POWER RELATIONS

Let us begin by stating explicitly the line of reasoning which led to the above four diagrams. Fig. 1a is simple. The normal ear reads zero by A C and B C because that is how the machine is constructed. The attenuator dial is so built that when it shows zero by A C the acoustic energy given out by the telephone is just audible to the normal ear (in a silent room). Similarly, when the attenuator reads zero for B C (and usually this is at a different point from the A C zero) the vibrator just produces an audible sound when placed on the mastoid of a normal hearing individual. It follows that in each case the same amount of power is being delivered to the organ of Corti, i.e., just enough to evoke an auditory sensation.

## THE A C POWER RELATIONS

Does this mean that the same amount of power is being delivered by the telephone and vibrator respectively? By no means! Have we any means of comparing those two quantities? At first sight that does not appear to be difficult. We start off by estimating in microwatts the intensity of the sound which just evokes auditory sensations. At 1000 cps this is about  $10^3$  microwatts. We now encounter our first difficulty. This is the sound energy *offered* to the drum. It is not the sound energy *taken up* by the drum. The ability of a membrane to take up sound energy depends on how closely matched its impedance is to that of the vibrating medium. Considerable variations of impedance occur at different frequencies and different intensities owing to contractions of the tensor tympani and the physical characteristics of the drum.

This difficulty becomes formidable later on but for the moment we can brush it aside, because we are not at present interested in the amount of energy taken up by the drum. We are only interested in the amount offered, and that is a readily understood and measurable quantity.

Let us now make the assumption that at threshold (at 1000 cps) the power consumed by the inner ear is  $10^3$  microwatts. We may then estimate the efficiency of the A C apparatus for 1000 cps at threshold



## A. Tumarkin

by comparing the power consumed by the inner ear with the power offered to the drum. This gives us an efficiency ratio of  $\frac{10^{-5}}{10^{-3}} = \frac{1}{100}$ , but we must be careful to stress that these figures only apply for 1000 c.p.s. at threshold. Now suppose we increase the test tone 100-fold i.e. 20 db. Will the power consumed by the inner ear be similarly increased. That is almost certainly not the case, but, being still in search of a simple hypothesis, let us assume that it is so i.e. at all frequencies and all intensities the power delivered to the inner ear is one hundredth of the power offered to the drum.

For reasons which will appear later, we now push our analysis two steps backward, namely to the electrical energy in the coil of the telephone.

This energy is transformed into mechanical energy in the vibrating diaphragm and from there it is transformed into sound energy.

In a well constructed telephone there is a fairly linear relation between acoustic output and electric input. Suppose that factor is one-tenth. Then at threshold the electric output of the audiometer must be  $10^{-2}$  microwatts i.e. 1,000 times the power delivered to the inner ear. This relation is graphically shown in Fig. 2. This shows the relation between

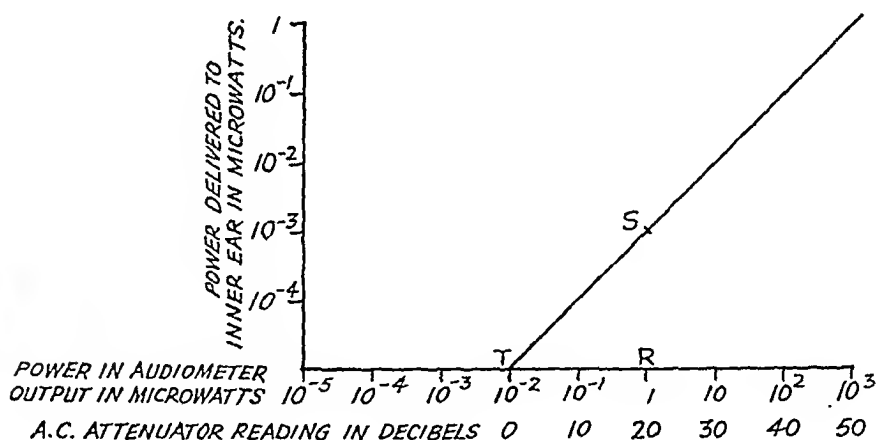


FIG. 2.

A.C. PERFORMANCE OF A NORMAL EAR.

electric power delivered by the audiometer output circuit to the coil of the telephone and the mechanical power delivered to the inner ear. The co-ordinates represent the energy delivered to the inner ear. Point T represents the threshold i.e. the point at which the inner ear is receiving  $10^{-5}$  microwatts. At that point the audiometer output is  $10^{-2}$  microwatts.

The A.C. attenuator dial would read zero for point T. When the dial is rotated to R the audiometer output is increased by 20 db. i.e. 100-fold.

## Quantitative Estimations of Bone Conduction

We have agreed to assume that the power delivered to the inner ear increases *pari passu* with the audiometer output i.e. it rises from  $10^5$  at T to  $10^3$  at S i.e. RS equals TR. This relation holds for any intensity of sound and it is clear that the graph must be a straight line at 45 degrees. We say that there is a linear relation between audiometer output and inner ear input.

### THE B C POWER RELATIONS

Now let us turn to the vibrator. We have agreed that at threshold (1000 c p s) the vibrator is supplying the inner ear with the same power as the telephone i.e.  $10^5$  microwatts. Can we determine for the vibrator an efficiency factor comparable with the figures we have already obtained for the telephone?

What must we measure? In the case of the telephone we had no real difficulty. We measured the acoustic energy of the sound field, but what are we to measure in the vibrator? Shall we measure the mechanical energy in the vibrating button, or the total power delivered to the skull. The latter would include the energy dissipated in the soft tissue, plus the energy used up in rocking the skull as a whole, plus the energy used up in causing waves of compression to traverse the skull. Or shall we measure the power delivered to the inner ear itself. The latter would be an ideal solution, and, as I shall show later it is the one we must obtain, but at present we have no knowledge whatsoever of its value.

What of the power delivered to the skull. The interested reader is referred to the monumental works of Barany and Békésy on that problem. Their pioneer work deserves to be more widely recognized. They have clearly outlined the complexity of the problem and have indicated the lines along which future research must proceed. Their own results are however, not sufficiently generalized to serve as a theoretical basis and indeed it must be confessed that we still do not know exactly how the skull vibrates or how the inner ear picks up those vibrations.

These problems have apparently not occurred to the manufacturers of hearing aids. At any rate, the writer has never found any reference to the matter. The simple fact emerges that the manufacturer is content to measure the electric power in the output circuit of the audiometer. Let us therefore measure that quantity. At any rate it has the advantage that it is directly comparable with the A C tests.

Let us assume that it is 10 microwatts (Fig. 3) so that the efficiency of B C at threshold at 1000 c p s is  $\frac{10^5}{10} =$  one millionth. As before, let us assume that that factor is constant for all frequencies and all intensities. Then we can draw the resulting linear relation for B C as in Fig. 3. The threshold is at M and by similar reasoning to the above we draw the

B.C. graph MQ at 45 degrees. This is our first goal, a basis for comparison between B.C. and A.C.

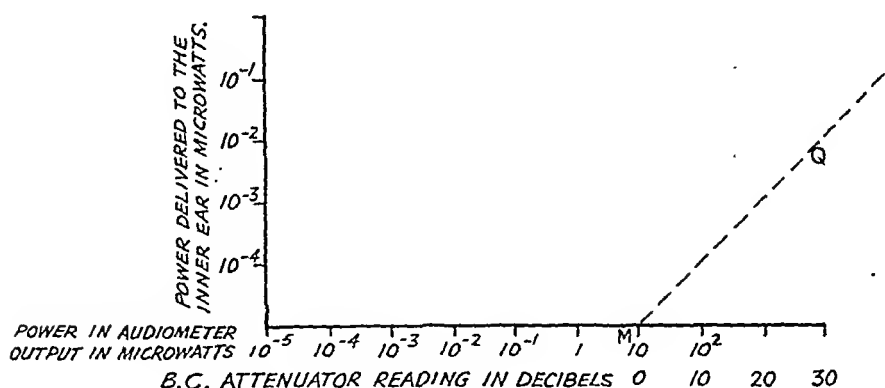


FIG. 3.

B.C. PERFORMANCE OF A NORMAL EAR.

## DEAFNESS EXPRESSED IN TERMS OF POWER CONSUMPTION IN INNER EAR

Now let us apply this graph to a patient with a pure perceptive deafness of 20 db. [Fig. 4]. First consider his A.C. test. In accordance with all our assumptions the air attenuator dial must be rotated to point R and the power delivered to the inner ear is represented by the ordinate RS. Now consider his B.C. tests. As he has a pure nerve deafness, the same amount of power must be delivered to the inner ear. We find point P on the B.C. graph such that the ordinate PN has the same height as RS. When the B.C. attenuator is rotated to N the vibrator is delivering the same amount of energy to the inner ear as was delivered by the telephone at R. It is easy to see that the B.C. attenuator reading will be 20 also.

We do not seem to have achieved very much with this elaborate discussion. In fact, at first sight we seem to have argued in a circle. We have demonstrated the "fact" that in pure nerve deafness, the B.C. attenuator reading is the same as the A.C. attenuator reading—(Fig. 4). Actually, this is all we set out to do i.e. to render explicit the train of reasoning which leads a clinician to expect this to be the case. But at what a cost have we reached this conclusion. The various "simplifying" assumptions which I have repeatedly made as to the linearity of relations were absolutely necessary in order to achieve this result. The result in fact depends on the assumption that TRS and MNP are similar triangles. But it is in the highest degree unlikely that that is the case. At any of the points at which energy transfer takes place i.e. Electrical energy in coil of telephone into Telephone diaphragm

# Quantitative Estimations of Bone Conduction

Combined AC and BC readings in pure perceptive deafness of 20 db assuming linear relations throughout

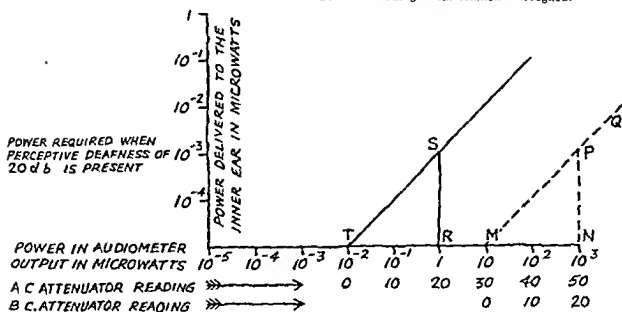


FIG 4

AC loss =  $TR = 20$  db

BC loss =  $MN = 20$  db

In each case the inner ear requires  $10^{-3}$  microwatts, i.e. points S and P respectively so that  $RS = NP$

$TR = MN$  because we have made TS parallel to MQ

Combined AC and BC readings in pure perceptive deafness of 20 db—admitting that the relations are non linear

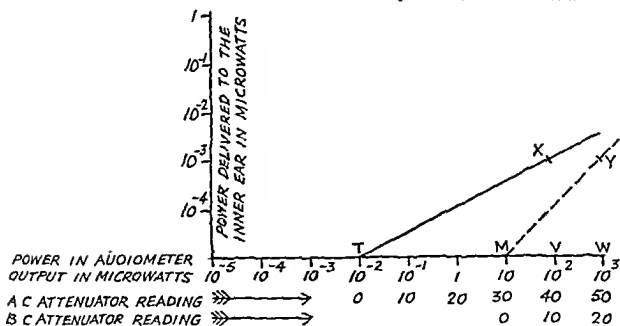


FIG 5

As in Fig 4, inner ear requires  $10^{-3}$  microwatts, i.e. points X and Y so that  $VX = WY$  but as TX is no longer parallel to MY TV is not equal to MW.

AC loss =  $TV$  appears to be 40 db

BC loss =  $MW$  " " " 20 db

Diagnosis " " " mixed deafness

vibrations, Telephone diaphragm vibrations into sound waves in air, Sound waves into drum vibrations, drum vibrations into ossicle vibrations, and a similar set of transfer points is the B.C. route, the relation is likely to be non-linear.

The theory outlined by Fowler assumes that when the B.C. attenuator is rotated to any point—say 20 db., it delivers to the normal inner ear a quantity of energy which is exactly the same as the quantity delivered by the A.C. telephone when its attenuator reads 20 db. The existence of all these potential non-linear relations quite invalidates that theory. Suppose for example the true state of affairs were as shown in Fig. 5. Compare points X and Y. In each case the power delivered to the inner ear is  $10^{-3}$  microwatts i.e. they have the same loudness, but X is an air conducted sound registered on the audiometer as 40 db. whilst Y is a B.C. sound of only 20 db. Suppose a patient with pure nerve deafness required  $10^{-3}$  microwatts at threshold, then his audiogram would be as shown in Fig. 1 (d) i.e. he would be diagnosed as a "mixed deafness".

## THE FALLACY

The origin of this confusion should now be apparent. The clinician is thinking in terms of the energy delivered to the inner ear. The audiometer manufacturer thinks in terms of the energy output of his instrument. If the two quantities were linearly related no harm would accrue. Unfortunately, it is most unlikely that such a simple relationship exists and therefore the quantitative comparison between B.C. and A.C. must be inaccurate and misleading.

## THE SOLUTION

Is the problem therefore insoluble? Not necessarily. We can at any rate get an approximate answer as follows: in Fig. 6 I have drawn two identical audiometers each giving out the same tone—say 1000

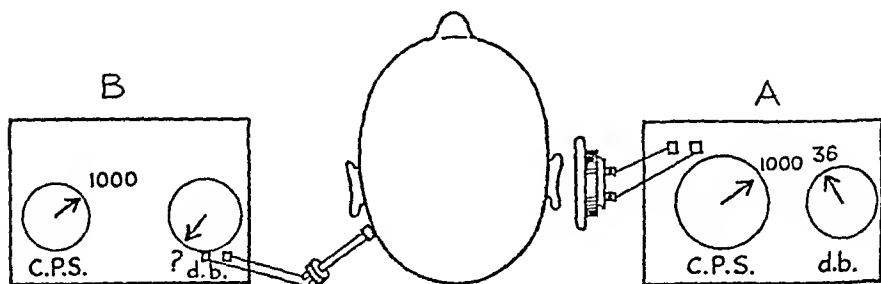


FIG. 6.

### THE PHYSICAL FALLACY.

The B.C. vibrator must be calibrated by a loudness balance against the telephone and not against the power in the audiometer output.

## Quantitative Estimations of Bone Conduction

c p s Instrument A is delivering by air B by bone Set A to 30 db and let a normal individual listen to it Now apply the vibrator to his mastoid and rotate its attenuator until the B C sound is as loud as the A C sound This is a standard type of loudness balancing and presents no difficulty to a trained observer When the balance has been achieved we know that the vibrator is delivering as much acoustic energy to the inner ear as the telephone We do not know how much that energy is—nor do we care We call that point on the B C attenuator dial 30 db regardless of its value measured against the electrical energy in the coil Such loudness balances must be made at other points—say 10, 20, 30 db up to 70 db or more and intervening points can easily be interpolated Such a B C scale is absolutely arbitrary and will almost certainly be much more complicated than the simple sub-divisions of a logarithmically wound potentiometer on the output circuit of the audiometer It might turn out that enormous variations exist between different normal individuals This would almost deal a death blow to any hope of a rational theory of B C tests I believe however, that this is unlikely to be the case What is possible is that the calibration for one frequency may be different from the calibration for another In exactly the same way, the subjective loudness of the sound in phons differs considerably from its objective intensity in db with variation in pitch and intensity (see Harvey Fletcher) This difficulty is easily surmounted by constructing the necessary corrections on the audiogram blank

Such an audiometer would enable us to deal with all our physical difficulties outlined above Would it therefore solve our problem? By no means We still have our physiological or pathological problems I started with the assumption that B C loss was entirely due to nerve lesions and that conductive lesions could not diminish hearing by bone. Unfortunately that assumption is too sweeping Fowler believes that round and oval window lesions can interfere with B C Guild and others have suggested that microscopic fractures in certain regions may interfere and certainly the results of fenestration seem to indicate that B C loss is not always due to a nerve lesion This is a subject of urgent importance The audiogram has been falling into disrepute lately because of its obvious inaccuracy It is perhaps unfortunate that quantitative estimations have been attempted with such a faulty instrument The older tuning fork tests were in the main, qualitative and not being so ambitious, they did not incur so much criticism

The pitfall lies in the attempt to compare A C and B C quantitatively Rinne's test is essentially qualitative, although even so its results are frequently ambiguous and confusing Schwabach compares patients' B C with the doctor's B C Thus, the tuning fork tests have been regarded by many clinicians as more *reliable* than the audiogram This

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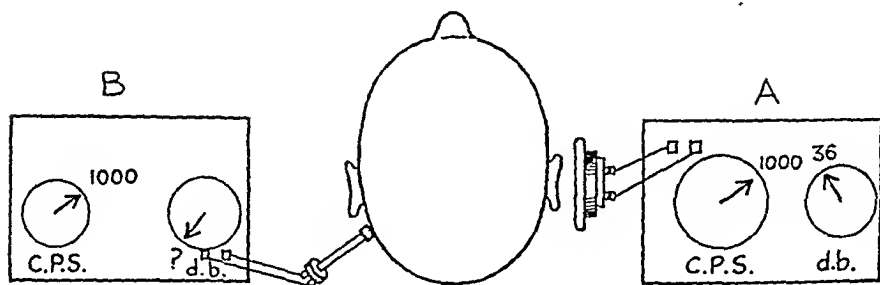


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# Quantitative Estimations of Bone Conduction

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FOWLER, E P, 1935, Symposium 'Tone localization in the cochlea' *Annals of Otol Rhinol*, xlv, 736

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## II

### Introduction

In the first part of this article, I discussed the physical fallacies inherent in our present technique of B C audiometry, and I indicated a method whereby those fallacies might be corrected. In this part I wish to discuss the physiological or pathological fallacies. We shall find ourselves confronted by problems to which the answer is as yet unknown, but the method of our analysis will itself reveal the lines along which research must proceed if we are ever to attain an understanding of the significance of B C audiometry.

### MODES OF VIBRATIONS OF THE SKULL

We open our enquiry by asking what happens to the skull when a vibrator is placed on it. In order to answer that question, we first consider what happens in certain much simpler physical conditions.

AX is an infinitely long column of metal. If it is suddenly tapped by a hammer at A we know that the lamina A' undergoes compression (Fig 7)

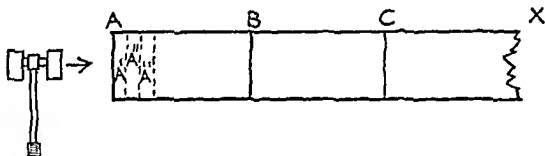


FIG 7

TRANSMISSION OF SOUND WAVES IN AN INFINITE MEDIUM

It lurches against its right hand neighbour A'' which also becomes compressed. A'' passes the compression on to A''' during which time A' is expanding back to its normal position. Thus, a wave of compression traverses AX. If we replace the hammer by a vibrator, we set up in AX a true sound wave. Every lamina of AX in its turn undergoes rhythmic condensation and rarefaction. Every particle swings rhythmically to and fro with a phase which depends upon its distance from A and also upon the wave length of the sound. For instance if the vibrator has a frequency of 1000 c p s the wave length will be about four feet. That is to say at intervals of four feet from A there will be laminae B, C, etc., which are moving exactly in step with A.



## A. Tumarkin

What happens if AX is *not* an infinite medium? Suppose instead that it is merely a lamina A'. When struck by a hammer, it lurches to the right but it does not encounter the elastic resistance of its neighbour. It is free to travel in air and it does so. Thus, instead of undergoing compression, it acquires a mass velocity. It moves as a unit with a velocity which depends on its total mass and the energy of the blow. Similarly under the attack of a vibrator it merely swings rhythmically to and fro. Thus two entirely different phenomena occur according to whether the medium is infinitely large or infinitely small.

What happens when the medium is intermediate in size? Both phenomena occur, but one or other will predominate according as the medium is large or small. "Large or small" must be construed by reference to wave lengths. Thus a medium one foot long would be "small" if attacked by a vibrator at 100 c.p.s. but it would be large for a frequency of 10000 c.p.s.

In general a finite medium when attacked by a vibrator will :

1. Swing rhythmically *en masse* i.e. it will undergo pendular translatory movement.
2. Transmit true sound waves i.e. it will undergo rhythmic condensations and rarefaction.

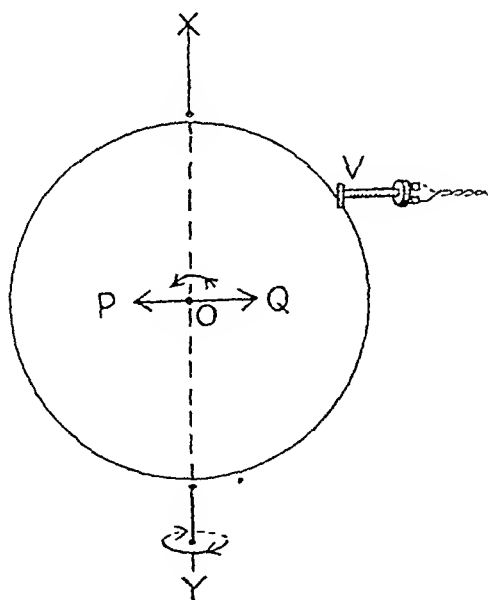


FIG. 8.

THREE POSSIBLE MODES OF MASS MOVEMENT.

1. Rotary movement around a vertical axis through O.
2. Rotary movement around a sagittal axis through XY.
3. Translatory movement along PQ.

## Quantitative Estimations of Bone Conduction

Now apply these ideas to BC tests. For simplicity we regard the skull as a solid sphere and not a hollow bony capsule containing brain tissue. Also we disregard rotary *en masse* movements. In Fig 8 a vibrator applied at V to a sphere could set up three different types of movement

- 1 Rotary movements round a vertical axis through O
- 2 Rotary movements round a horizontal axis through XY
- 3 Translatory pendular movements from right to left and back again

We choose to disregard 1 and 2 because following Barany we regard them as probably unimportant. Furthermore their investigation presents peculiar difficulties. Nevertheless it is right to note them so that when more refined methods of research are available it may be possible to review their significance.

For the present we confine ourselves to

- 1 Translatory *en masse* movements
- 2 True sound waves

and we shall see that both factors are capable of setting up the sensation of hearing.

### THE FALLACY

It appears therefore that in BC audiometry we are attempting to measure at least two very different phenomena. Despite the obvious possibility that they can vary independently we attempt to specify them by a single index—the BC impairment on the mastoid. Hence the physiological fallacy.

### TRANSLATORY MOVEMENT

How do the two factors work? Consider first translatory movements of the skull. In Fig 9 I have shown the conventional diagram

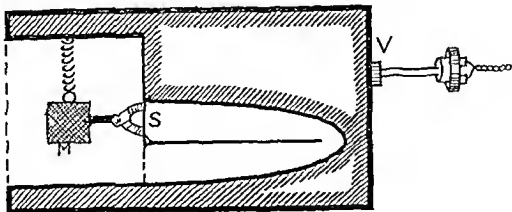


FIG 9  
THE INERTIA TRANSLATORY EFFECT

of the cochlea with its stapes in situ. Instead of the malleus and incus I have shown a mass M lightly suspended. What happens when a vibrator

is applied to such a "skull" at V". Confining ourselves to translatory movements we see that owing to inertia M will lag behind the general movement, so that S undergoes corresponding oscillations. For a given force in the vibrator, the oscillations of S will depend on:

1. The site of application of the vibrator.
2. The freedom of the suspension of M.
3. The mass of M.

Returning to the skull, we first make allowance for the suspension. The ossicular chain is much more constrained than M in Fig. 9. Regarding the tympanic membrane as confined to the plane ABCD in Fig. 10 we see that the vibrator will have minimal effect along the circle

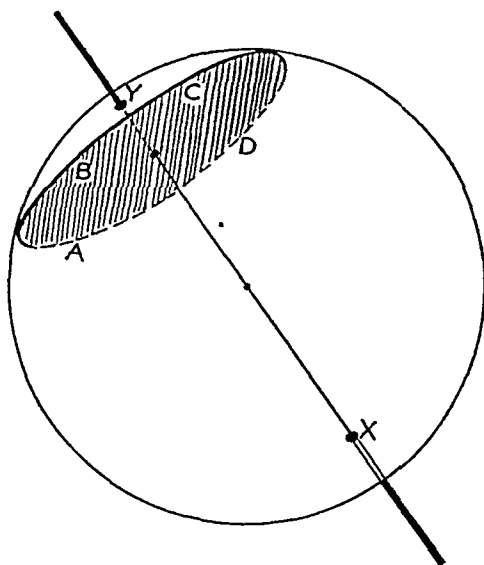


FIG. 10.

THE CIRCLE OF INDIFFERENCE AND THE POLES OF MAXIMUM EFFECT.

ABCD and it will have maximal effect at the two points X and Y where the axis of the plane emerges from the skull. This argument is of great importance. If it is correct it should be possible to demonstrate such maximal points and also a circle of indifference corresponding to ABCD by a suitable exclusion of other variable factors.

Suppose the constraint is increased. Let M be rigidly fixed to the casing. Clearly it follows the casing movements immediately. There is no phase lag and no B.C. effect. Similarly if S is rigidly *ankylosed* there is no possibility of inertial translatory effects from the impact of the ossicular chain. This point should be carefully noted. Its bearing on otosclerosis is clear and it gives us our first glimpse of a possible mechanism whereby B.C. in conductive lesions might be diminished.

## Quantitative Estimations of Bone Conduction

The effect of the mass of  $M$  depends not only on its magnitude, but also on its point of application, i.e. its centre of gravity. Suppose for example the incudo-stapedial joint is separated. The effective mass is now merely the stapes so that we expect the effect to diminish. The relation of the centre of gravity to  $BC$  effects has been discussed at great length by Bárány. The writer is not prepared to agree with many of Bárány's points, or indeed with his main thesis to the effect that the whole design of the mammalian middle ear aims at suppressing bone conduction. This theory is important enough to merit separate discussions and so for present purposes we content ourselves with recognizing that the arrangements of the main ossicular mass above the axis of rotation and the main elastic components below the axis may have such an effect. If that is the case, then changes in those components must increase bone conduction. According to Bárány, the chain is so constructed and balanced that  $BC$  is a minimum consequently erosion of the ossicles, loading with granulation, perforation of the drum etc., should all result in *increased*  $BC$ . We are in no position as yet to distinguish clinically between all these possibilities but we are at least entitled to recognize that if inertia translatory effects occur at all, then it is possible for them to be disturbed. In some cases this will result in increase, in others in a decrease of  $BC$ . In all these cases the changes visualized are in the conductive mechanism. They produce their effect quite independently of the condition of the organ of Corti.

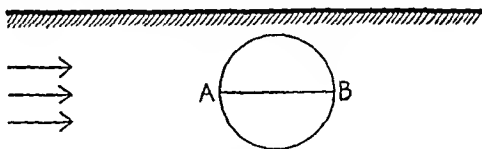


FIG. 11  
A PARADOX

Sound waves in the skull need not necessarily produce a sensation of sound

### COMPRESSION AND DISTORTION

Now let us turn to compression effects. First we note the curious paradox that these true sound waves in the skull need not necessarily produce sympathetic vibrations of the basilar membrane, i.e. they need not necessarily produce a sensation of sound.

Let a string  $AB$  be stretched across a capsule floating in water. If the sound wave encounters the capsule in the axis  $AB$  only a rhythmical longitudinal shortening and lengthening of the string will occur. No true transverse vibrations will occur even if the string is resonant to the sound.

wave employed. Particles A and B move in different phase, but only along the line AB. There is no tendency to transverse displacement.

Of course if the sound wave comes in obliquely there will be such a phase lag in a transverse direction, resulting in a mounting transverse displacement, especially if string and sound wave are in resonance.

This presumably is what happens in the skull. The compression of the sound wave sets up an asymmetric distortion of the otic capsule with resulting transverse displacement of the basilar membrane. In particular the corresponding basilar fibre falls into resonant vibration. This should therefore be described as a distortion effect and it differs from the true compression effect on which so much stress has been laid by Bekesy and others. The latter occurs as follows. Fig. 12. Imagine

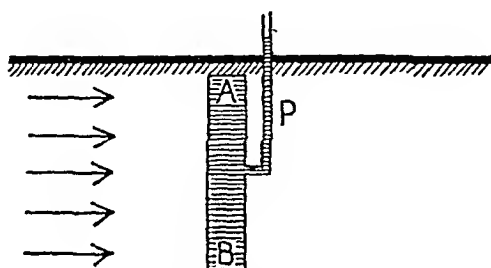


FIG. 12.

THE COMPRESSION EFFECT.

This depends on different compressibility of fluids inside and outside AB.

a small capsule AB floating in water traversed by a sound wave. Regarding AB as a lamina we envisage it undergoing rhythmic contraction and expansion. Thus, if a small outlet pipe P were inserted we might at first sight expect the fluid in AB to surge up and down P with each pulse of the sound. A little consideration, however, reveals that this is by no means necessarily true. Suppose AB contains fluid which is *identical* with the surrounding medium. Then the fluid inside the capsule is condensed (and rarefied) to exactly the same extent as the surrounding fluids. The previous theory that the level in the capillary outlet P would rise and fall really assumes that the contents of AB are *incompressible* (or at any rate *less* compressible than the surrounding medium. How is it with the ear? In this case the capsule AB is represented by the labyrinthine fluids and tissues. The petrous represents the surrounding medium. We are perhaps entitled to assume that there is sufficient difference in compressibility between bone and fluid to produce a true compression effect, but that is certainly a matter calling for investigation.

Even granting such a difference we have certain other assumptions to make before we attain the necessary conditions for auditory stimulation.

## Quantitative Estimations of Bone Conduction

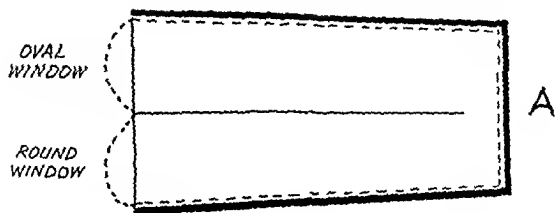


FIG. 13.

Uniform compression of the two scalae fails to disturb the basilar membrane.

If the compression is uniform—as in Fig. 13 both windows will bulge equally and the basilar membrane will remain symmetrically stationary. The necessary distortion of the basilar membrane can occur if one window is more compliant than the other as in Fig. 14.

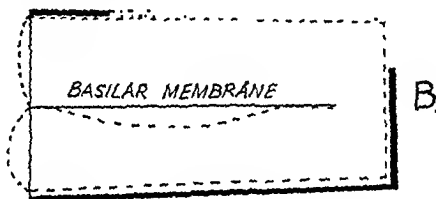


FIG. 14

If one window is more rigid than the other, there will be differential movement of the basilar membrane

Finally, if, as in Fig. 15 extra fluid is forced in from the semicircular canals—the requisite differential movement will occur. The above figures are taken from Bekesy.

Let us now consider under what conditions these effects might be altered. Clearly changes in the elasticity of the windows might have such an effect. Post-suppurative fibrosis—radical mastoidectomy etc., would presumably modify compression B C effects.

What about the site of application of the vibrator. Here we encounter considerable difficulty and much will depend on the wave length. To begin with, we note that the wave starts from a small area under the vibrator and spreads throughout the skull. We might expect therefore that the intensity would be greatest immediately under the vibrator and would diminish at more remote points. We must not however

forget that when the wave reaches the periphery of the skull it is reflected back as a wave of rarefaction just as in an open organ pipe. In the case of high frequencies it is even possible that standing waves occur. If the phenomenon of compression B.C. could be isolated, it might theoretically be possible to map certain points on the skull at which certain frequencies would be quite inaudible by bone conduction. At other points freak loudness might occur. This possibly explains the occasional case in which B.C. is louder in the contralateral ear.

This review of the relevant factors in B.C. hearing is admittedly superficial and probably very incomplete. A satisfactory evolution of all the components will only emerge as a result of practical research. The present analyses is only proposed as a simple working hypothesis out of which certain lines of research might evolve. Let us therefore correlate our findings with a view to extracting some suggestions for research.

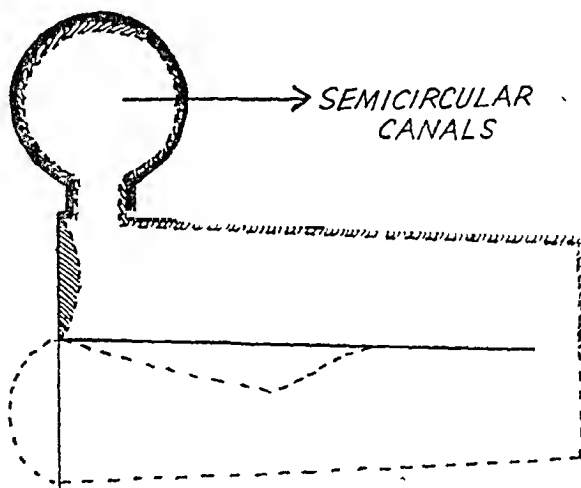


FIG. 15.

Excess fluid movement from semicircular canals produces differential movement of the basilar membrane.

It must first be emphasized that any of the above mechanisms will have a diminished effect if the end organ has deteriorated. Inner-ear deafness *must* diminish B.C. hearing. It is clear however that the converse is not true. Diminished B.C. is not *necessarily* due to inner-ear lesions.

The inertia translatory effect is entirely manifest *via* the middle-ear structure, it possibly has a circle of minimal effect and two poles of maximal effect. It diminishes in significance as the frequency rises.

The distortion and compression effects are also partly affected by

the middle ear structures, but to a much less extent than the inertial effects. In the writer's opinion, the compression and distortion effects are least affected by variations in the conductive apparatus. It follows that if we could devise some means of evaluating those effects independently we should have the most reliable index to the condition of the inner ear. It is only fair to say that this opinion is not universal. Guild for instance claims that sound waves are selectively conveyed to the inner ear by certain special trabeculae in the subaditus region. He has demonstrated that fractures and even atrophy of these trabeculae can occur and in such cases the BC will be impaired even though AC is normal. This possibility must be admitted but in the writer's opinion there is no reason to expect it to be a common phenomenon. Authenticated cases of normal AC with reduced BC are excessively rare.

## RESEARCH PROPOSED

How shall we set about disentangling this network of variables? First we need an audiometer calibrated by the loudness balancing method which I have outlined in the first part of this article. Next we need a series of intelligent patients with monaural hearing. Cases of unilateral labyrinthectomy GSW etc. would be suitable. In that way we eliminate our first source of confusion—viz simultaneous stimulation of two ears. I do not discuss here the precautions to be taken with regard to background noise, occlusion of the meatus, clenching of the teeth etc. The confusion which can arise from neglect to eliminate these variables is well known and the necessary precautions are equally well known.

Let us assume we have suitable audiometers, intelligent monaural patients and adequate equipment. Our next step will be to analyse clinically their 'healthy' ears. It should be possible to find all types of cases from apparently perfectly normal to extremely deaf. Furthermore in certain cases it should be possible to say that the trouble is very probably an inner ear deterioration. This diagnosis will of course only be tentative—on the basis say of an apparently normal drum high tone loss by AC etc. In other cases a tentative diagnosis of middle ear deafness may be possible on the basis of suppuration or periotic fibrosis. We shall then proceed to investigate them for a possible 'circle of indifference' and associated poles of maximal sensitivity. This of course is on the assumption that inertial translatory forces are significant. This investigation should start with low frequencies in accordance with the theory that the lower the frequency the more will translatory effects predominate. The writer has already attempted this investigation on a group of patients who had had unilateral labyrinthectomy for intractable Meniere's disease. The results were far from convincing but it is to be hoped that a more serious investigation will be undertaken under more suitable circumstances. If such a circle



of indifference" could be demonstrated, it should be possible to demonstrate its disappearance at high frequencies, when presumably the distortion effects would predominate.

Tests of this type on a series of normal ears should give us some standard of comparison. We could then proceed to test a supposed case of pure inner-ear deafness, expecting to find a uniform loss of sensitivity. The "circle of indifference" should still be present and the poles of maximal sensitivity. Lastly cases with middle-ear disorganization would be examined. In these the "circle of indifference" and the poles would not be demonstrable. On the other hand high frequency B.C. might be normal.

The above outline is, of course, entirely tentative. No research worker expects to pursue his work along the exact lines of his original plan. I shall be satisfied if the analysis has contributed a little towards the formulation of the problem.

## Summary

1. The physiological fallacy in B.C. tests is analysed.
2. Certain deductions are made as to possible variations of B.C. with frequency and with point of attack of the vibrator.
3. Suggestions are made as to lines of research which might throw some light on the mechanism and diagnostic significance of B.C. tests.

## Mathematical Analysis

A linear equation is one which is representable in Cartesian co-ordinates by a straight line. Its most general algebraic form is  $y=mx+c$  where  $m$  and  $c$  are arbitrary constants. For simplicity we ignore  $c$ . The equation  $y=mx$  is a straight line through the origin inclined at an angle  $\theta$  such that  $\tan \theta = \frac{y}{x} = m$ .

Clearly if  $x$  is multiplied by any factor  $y$  is equally augmented e.g. if  $x$  is doubled so is  $y$ .

Let  $Y$  be the power consumed in the inner ear in producing the auditory sensation.

Let  $X$  be the power in the audiometer output circuit. Clearly  $Y$  depends on  $X$ . But the exact relation will depend on whether the energy is transmitted by A.C. or B.C.

We therefore distinguish  $X_a$  the audiometer power when the phone is jacked in, and  $X_b$  the audiometer power when the vibrator is jacked in and we write equations  $Y=\phi(X_a)$      $Y=\psi(X_b)$ .

Now consider the threshold of audibility. The inner ear is consuming a certain amount of energy which we will represent by  $Y_0$ . In order to produce that sensation the audiometer output by air is  $x_a$  and by bone is  $x_b$ . We write  $Y_0=\phi(x_a)=\psi(x_b)$ .  $x_a$  and  $x_b$  are constants.

## Quantitative Estimations of Bone Conduction

Now for the fallacy Consider pure nerve deafness say of 30 db It is assumed that such a patient will just hear the signal by A C when the audiometer output is increased by 1,000 and that similarly he will just hear by B C when the audiometer output is increased by 1,000 Let  $Z_0$  be the power consumed in that deaf patient's ear at his threshold

Then these assumptions imply that

$$Z_0 = \phi(1,000 \lambda a) = \psi(1,000 \lambda b)$$

The argument holds for all degrees of nerve deafness i.e. instead of 1,000 we write  $p$  where  $p$  has any value between 1 and  $10^{12}$  (or whatever is the range between lower and upper limits)

Now it is easily seen that such a relation  $\phi(p \lambda a) = \psi(p \lambda b)$  can only hold if both  $\phi$  and  $\psi$  are linear (excluding of course the solution  $\phi = \psi$  involving  $\lambda a = \lambda b$  which we know to be incorrect)

Is it possible for  $\phi$  and  $\psi$  to be linear? In other words when a noise is augmented a million fold, does the inner ear consume a million times as much energy? I doubt that very much For one thing it implies that the ear has no defence at all against loud noise The transmission by bone is even less likely to be linear in view of the multiplicity of factors involved and yet if these functions are not linear it is quite unjustifiable to compare A C and B C audiograms as we do in quantitative tests

*Note* — A linear function may slope at any angle i.e.  $\phi$  may vary between  $0^\circ$  and  $360^\circ$  and yet the reader will observe that I have drawn the graphs in Figs 2 and 3 in each case at  $45^\circ$  The reason is that these diagrams really express the relations between the *logarithms* of the quantities in question

Thus let  $y = mx$  so that  $\log y = \log x + \log m$

The slope of the graph (i.e.  $\tan \theta$ ) in the first case is given by  $\frac{dy}{dx} = m$

but in the second case it is  $\frac{d(\log y)}{d(\log x)} = 1$

Thus in the case of any linear function drawn logarithmically  $\tan \theta = 1$ , i.e. the line slopes at  $45^\circ$

## ON DIRECTIONAL HEARING

By L. B. W. JONGKEES and J. J. GROEN (Utrecht)\*

BESIDES being able to perceive the sound qualities of height and intensity, man is capable of projecting the perceived sound into space. He can estimate more or less accurately the distance and the direction from which a sound is reaching him. The investigation of this problem was started long ago by physicists and technicians, especially in connection with the stereophony in acoustical engineering, and much information has already been gained.

Briefly for directional hearing in the horizontal plane three factors are relevant namely: the difference of intensity in which the sound reaches both ears, the difference of phase between the tone reaching the left and the right ear, and for discontinuous sounds the difference in time of arrival of the sound at the two ears. For all these factors two organs are required to make directional hearing possible. Indeed it is well known that persons with one deaf ear are hardly able to determine the direction of a sound.

The occurring intensity differences are however only appreciable for high tones. Sivian and White (1) have proved experimentally that the difference is practically zero below 300 Hz. These intensity differences are caused by diffraction phenomena which only occur if the wave length is small compared with the dimensions of the head. Stewart and Hovda (2) found that it was possible to create a directional sensation by presenting sounds with an intensity difference to the two ears. The results were not very steady though and differed greatly from one person to another. However, a logarithmic relation between the angular displacement of the sound image and the intensity difference at the ears could be established and was later corroborated by von Békésy (3). The authors believe that in the natural hearing process the directional sensation is caused by quality differences in complex sounds owing to these diffraction phenomena for the high components.

As the intensity differences are certainly insufficient for an explanation for low tones the phase difference was considered. Rayleigh and Bowlker (4) suspected that the phase influences this process, but Firestone and Wightman (5) proved that it was hardly possible to determine the direction of a pure tone, presented with a phase difference to the two ears.

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## On Directional Hearing

Indeed it is very difficult to determine the direction of a sound, consisting of a purely sinusoidal tone, whereas it is much easier for complex sounds. For tones with frequencies above 1000 Hz no phase effect may be expected because one phase difference would then correspond to many directions. Van Soest (6) moreover demonstrated in an elegant experiment that beside the phase also the intensity must certainly be relevant. A tuning fork is placed on a long rubber tube in various positions. One then estimates how far the sound seems to be displaced to the right or to the left. When the fork is on the left half of the tube a maximal right sensation is never observed, even if the phase difference is such that this might have been expected.

Starting from the observation that the direction of a sound blast, a noise and a complex tone is much more easily determined than that of a pure sine, Hornborstel and Wertheimer (7) arrived at the theory that the difference in time of arrival of the sound at the right and left ear is responsible for the directional hearing. Von Békésy and van Soest and Groot (8) showed in laboratory experiments that a directional sensation really is connected with the time differences varying from a millisecc to a microsecc. There is of course much similarity between the theory of time difference of arrival and that of phase difference. The active phase difference is the time difference between two corresponding states of vibration at both ears. Above 1600 Hz also the time difference theory has to be abandoned, because then even the greatest phase difference corresponds to a time difference too small to permit detection of the sound source in the direction of the produced aural axis.

Finally at present combinations of the above mentioned theories are tried as a solution. For instance, according to Hartley and Fry (9) a combination of intensity and phase difference permits the estimation of the direction and even of the distance of the sound source. De Boer (10) concludes that for human speech 90 per cent have to be explained by intensity differences and 10 per cent by phase differences. This author stresses the point that the diffraction of sound by the head depends on the frequency. This dependence causes changes in timbre which may explain some directional hearing even with one ear. Moreover variations in timbre may help the localization in other than horizontal planes and decide between symmetric positions in front and back because of the irregular shape of the skull. Phase and intensity can only restrict the place of the sound source to a rotational cone (11).

According to van Soest (8) and Wallach (11) the exact spot on this cone is determined by small movements of the head.

Such is briefly outlined our present state of knowledge. For the physiologist various difficulties arise. Though these theories may be of great practical value and have already yielded important results for modern acoustic engineering they do not explain in any way the

physiological directional hearing process. The artificial experiments on directional hearing in the physical laboratories, with differences in intensity and phase cause no directional hearing in the physiological sense. No projection of the observed sound into space is obtained, with an associated directional sensation. On the contrary the sensation is as if the sound is located within the interior of the skull, more or less right or left. This was already observed by the investigators in this field and has given rise to the curious concept (or rather word) "virtual sound-image" (12).

### Experiments

We therefore had recourse to the most elementary problem and have investigated from what direction a test person with closed eyes estimates a sound is coming. In order to obtain objective and measurable results we used a graduated semicircle along which the sound source could be moved, and on which the test-person was requested to indicate where he thought the source was situated. For each experiment the subjective place as indicated by the test person was plotted as a function of the objective place, both in degrees as marked on the arc graduation. The experiments were performed in the sound- and reflection-free cellar of the aural clinic of the University of Utrecht. The radius of the semicircle used was 50 cm.

First a number of experiments was performed with various sorts of sound sources, as it was known that the place of origin is determined with varying ease for different sorts of sounds (13). Furthermore experiments were performed mainly in three planes: the horizontal plane, the vertical plane through the ears and the vertical plane through the nose, perpendicular to the former, designated as horizontal, vertical side and vertical front plane respectively. Moreover experiments were performed to eliminate the influence of the auricles by tying them flat to the head or by placing short tubes of about 6 cm. length in the auditory canal. Finally we did some experiments with one ear closed by a piece of cotton wool soaked in paraffin wax.

### Sound Source

As a source we used in the first place a telephone emitting purely sinusoidal tones from a frequency generator, operated at a frequency of 4000 Hz., 1000 Hz. or 500 Hz. These tones have a purely sinusoidal character as is shown by experiments with a kathode ray oscillograph. An effort to investigate the localization of tuning forks failed as it was impossible to excite the fork sufficiently to be heard at a distance of 50 cm. without noticeable by-sounds. Furthermore we have used organ pipes, namely a Galton whistle at about 12,000 Hz. an  $a^3$  and an  $e^2$  organ pipe. As a source of a more complex sound we took a watch. Experiments regarding the localization of the human voice with the aid of an

# On Directional Hearing

amplifier were discontinued, as the watch was a perfectly satisfactory representative of a highly complex sound source

In general we found in agreement with Reich and Behrens (13) that complex sounds, noises and ticking can be localized better than pure tones, especially in the vertical plane. No noticeable dependence on the height of the tone could be observed

## Plane of Investigation

With the experiments in the *horizontal plane*, when the sound source was moved along the semicircle at the height of the ears at a radius of 50 cm about the centre of the head we constantly found for all sources a good power of localization, at least in the region in front of the test person

We always observed a slight displacement of the sensation relative to the true source in the direction of the produced aural axis

Perhaps it is useful to show that the point where the source is believed to be is indicated by the test person with the finger. In a series

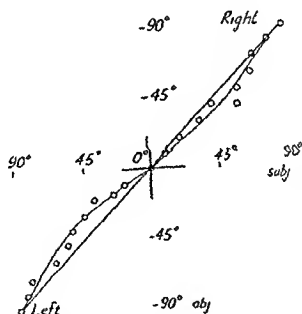


FIG 1

The curve represents the subjective localization of the sound source as a function of its place in the plane investigated. On the abscissa the subjective place on the ordinate the objective place of the sound source is indicated. The whole curve covers 180° with zero at the centre. The plane of investigation is horizontal, the sound source a pure sine of 500 Hz from a frequency generator. The zero is straight in front of the test person.

TYPICAL S SHAPE

of test experiments this form of indication proved to be very accurate. It was also shown that it was irrelevant which hand (the left or the right one) was used to point at the observed sound source. In this way a curve with a slight S shape is obtained (fig 1) for all kinds of sources. However good the localization in front of the test person may be, it

very difficult when the sound originates behind him. Besides the difficulty of the indication which may overcome with some patience, the phenomenon of mirrored images appears. Very often a sound originating from behind us is perceived as if coming from the same angle in front. Especially the pure sine gives rise to this misinterpretation. For instance of 13 cases investigated with a pure sine of 1000 Hz., 11 showed mirrored images for all or for the majority of points from the

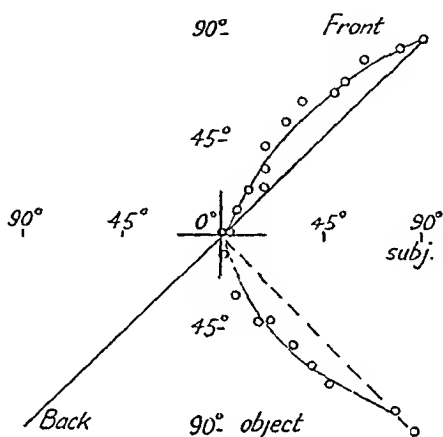


FIG. 2

Plane of investigation horizontal. Source: a<sup>3</sup> organ pipe. Zero point in the direction of the produced aural axis towards the left side. Further data as in Fig. 1.  
MIRRORED IMAGE

back to the front (fig. 2). With the pipes this only happened in 50 per cent. of the cases, with the watch only occasionally.

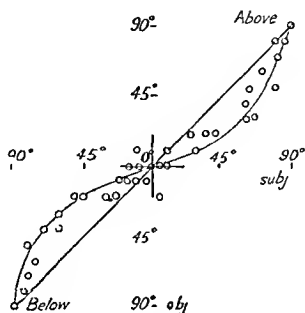
Great care has to be taken not to guide the interpretation by involuntary complex noises such as the breath of the experimenter, crackling of his shirt or suit, for this guidance is utilized immediately, usually unconsciously. Similarly, if one expects a sound to come from a certain direction, then it is indeed perceived from that direction. With some suggestion by the investigator in this way even a mirrored image from front to back side may well be obtained.

The presence of resonance planes has influence. In certain positions the entire mirrored images effect may disappear, for instance when lying on the ground or on a flat table during the observations. So far we could not discover sufficient regularity to draw any conclusions.

In the experiments when the source moved in the *vertical side plane* it was found that with the frequency generator practically no localization was possible. Mostly the sound was heard as if coming from a fixed point, independent of the true place of the source (formation of a sound centre).

## On Directional Hearing

With the organ pipes a good localization was possible, although here too an S-shaped curve resulted, which means that the impression is displaced outwardly i.e. upward and downward (fig. 3). It is curious



**FIG 3**

Plane of investigation left vertical side plane Source e' organ pipe Zero point  
in the direction of the produced aural axis towards the left side Further data as in Fig 1

that the localization for a high Galton whistle is more accurate than for a low  $e^2$  pipe. A few times a point is reflected relative to the horizontal plane and especially in the neighbourhood of the aural axis (the zero point of the scale) there is often some dispersion. The localization of the ticking of a watch is excellent.

If the semicircle is in the *vertical frontal position* relative to the test person the results are in the main lines similar to those obtained at the vertical side position. Again the localization of the pure sine tone is impossible, whereas pipes and a watch are well localized. Also here sometimes a slight S shape of the curve is observed, and once in a while mirrored images from above downwards. Moreover a phenomenon is here observed of which a slight suggestion could already be traced with the experiments in the vertical side plane namely a "compression" of the curve towards the zero point, that means that the sound when coming from exactly above or below, is perceived about  $20^\circ$  in the forward direction (fig. 4).

Also in the case of the vertical planes the curves are influenced by the addition of reflectory planes. If for instance the experiments in the vertical plane are performed on top of a table with reflecting leaf (in the other experiments we always worked on a table with a leaf of wire gauze, which doesn't reflect the sound) then for the lower part of



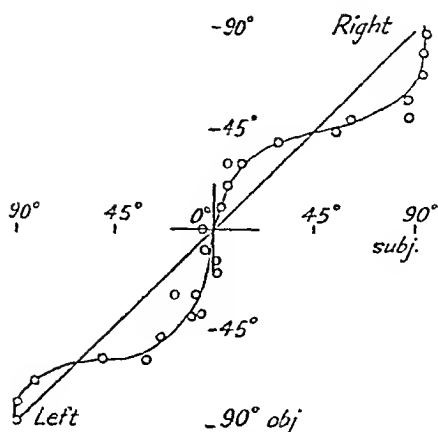


FIG. 7

Plane of investigation: horizontal. Source:  $c^2$  organ pipe. Tubes in the ears.  
Further data as in Fig. 1.  
DOUBLE S-SHAPE

### Closing of one Auditory Canal

Finally we investigated the effect of closing one of the auditory canals by means of a piece of cotton wool soaked in paraffin wax. This caused a decrease of the intensity observed by about 15 db, somewhat dependent on the height of the tone. No influence in the frontal vertical plane could be established. In the vertical side plane a displacement

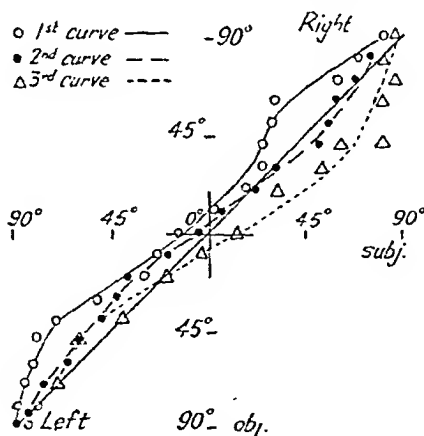


FIG. 8

Plane of investigation: horizontal front plane. Source: pure sine of 1000 Hz.  
Further data as in Fig. 1.

First curve: immediately after shutting off the right ear with a piece of cotton wool with paraffin wax causing an intensity loss of 17 db; displacement towards the left.  
Second curve: 2 hours later; decreasing deviation to the left.

Third curve: immediately after removal of the cotton wool; displacement towards the right.

## On Directional Hearing

of the observed sound source towards the normal ear is found, the same was observed in the horizontal plane. After several hours this deviation decreases however and is only slight after 24 hours. When after those 24 hours the cotton wool is removed from the closed ear, a displacement of the observation towards this ear takes place, which lasts only a few minutes (fig 8) so that during the determination the deviation fades away. Finally we were able to do some determinations with persons with hardness of hearing on one side. As long as the hearing was such that the investigated sound stimulated both ears, rather good directional hearing was present. If one ear was deaf or appreciably hard of hearing, the directional hearing was bad to very bad. But even with total deafness of one ear some directional hearing remains in the vertical plane and in the horizontal plane at the side of the sound ear. Further investigations are necessary before drawing definite conclusions.

### Summary of our own Experiments

Surveying our experiments it seems that few conclusions can be drawn from them regarding the nature of the process of directional hearing. We wish however to point towards a few considerations which may guide further experiments.

In the first place we could corroborate that it is easier to determine the direction of complex sounds than of a pure sine. It was not found to be true that a sound of 500 Hz could be localized more easily than one with a higher frequency. In the vertical side plane we even found a stronger S-curve for the former kind. The localization of the 4000 Hz sine or of the Galton whistle were certainly not worse than that of the 500 Hz sine and the  $e^2$  organ pipe.

We cannot explain the curious S-shape, observed almost constantly in the horizontal plane. It indicates that more accurate localization occurs in the direction of the produced aural axis and perpendicular to it than in any other direction.

The elimination of the auricles by tying them flat against the head or by placing tubes in the auditory canal makes vertical directional hearing almost impossible, whereas in the horizontal plane it also becomes more difficult. Also reflection has a strong influence on directional hearing, which should not be neglected.

A decrease of auditory acuity of one ear has not much influence on the vertical directional hearing and even total deafness of one ear leaves some sense of direction, both vertically and horizontally to the side of the sound ear. Hardness of hearing as a result of a swab of cotton wool soaked with paraffin wax has effect immediately, but after a few hours a loss of 20 db is already practically compensated. On the other hand a displacement of the sound image towards the ear from which the paraffined cotton wool is removed after an insertion of 24 hours, fades away completely in the course of a few minutes.

If it is true that intensity differences of the sounds at both ears are responsible for a large part of the directional hearing in the horizontal plane, it is, in any case, advisable to be aware of the fact that there is no fixed difference nor ratio, but one the interpretation of which is adapted to circumstances such as shutting off one ear. The experiments on elimination of the auricles indicate that, besides phase-, time- and intensity-differences still other factors play a part. Possibly the timbre differences owing to diffraction around the head are more important than has been hitherto believed.

No arguments could be derived from our experiments in favour of the view of van Soest (6) and Wallach (11) that by small movements of the head, the exact position of the sound source is determined on the rotational surface belonging to a given phase and intensity difference. No more than such a surface can be caused theoretically by those differences. Some data must be added to cause an exact localization of the sound source on this cone. It remains obscure from this standpoint why a pure sine is localized in the vertical direction with so much more difficulty than in the horizontal direction. The same is true for the elimination of the auricles. Moreover it is strange that a virtual sound image never gives rise to a sensation of higher or lower, but only left or right and perhaps forward and backward.

The impossibility of localizing pure sine tones, to determine the place when the influence of the auricles is eliminated, and the independence of deafening of one ear for the directional hearing in the vertical plane are all indications that here a different explanation will have to be sought and possibly also here the changes of timbre are important, owing to diffraction around the head and especially around the auricle.

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## CLINICAL RECORD

### THE HEARING LEVEL ELEVEN YEARS AFTER PARTIAL INTRACRANIAL DIVISION OF THE VIII<sup>TH</sup> NERVE FOR VERTIGO

By W STIRK ADAMS (Birmingham)

As the number of cases in this country of hemisection of the VIII<sup>th</sup> nerve, is likely to be few, this case record is presented eleven years after a successful operation

The patient was referred to me by Dr R Wilkinson, of Smethwick, in November, 1934. She was then 29, married, and gave a history of giddiness since she was quite young, though she was only able to remember her first attack at the age of 14. At that time if she stared at anything she was able to control the giddiness. In the attack external objects moved upwards to her left and downwards to her right, if she closed her eyes the attack passed off, and at that time there was no rotation of external objects. These attacks continued as part of her life but causing her little discomfort until 1930. She then had a tonsillectomy performed and following this she began to fall in her attacks, external surrounds rotated in front of her and if she held the table her surrounds became steady, though she sometimes fell across the table.

A gradual increase in her symptoms occurred after this, and she found herself unable to tolerate the cinema, unable to fix her vision on an object and quite unable to cut her nails. In the preceding six weeks she had become very much worse, and described severe attacks of "nerves" where something seemed to shoot up her left leg, her left side, her left arm, then putting up her hands she became hysterical. She became numb, could not feel herself, and she had the sense of rotating. Nausea had been severe but she had not vomited.

She had known her left ear to have been deaf for the previous fifteen years, with occasional discharge, and the last period of discharge had occurred three months earlier. Her right ear was not affected. Tinnitus, like steam and running water and like a bull blowing, had been noted in her left ear, and in the left side of her head, while headaches, located in her eyes and the back of her neck had also upset her. Occasional numbness had been present in both hands and both legs and a tight fullness in her epigastrium, when "she can't get her breath."

Periodic worsening of her symptoms, described as attacks, occur at intervals, the last attack began nine days previously and she had not fully recovered from it.

Examination in November, 1934 showed a normal drumhead on the right side, while in the left there was a wide postero inferior defect without exudate,

exposing the round window niche and showing the stapes. Her hearing for my whisper was at 6 feet distance from her right ear and 2 inches only from her left ; while tuning fork tests showed her able to hear the range between 4096 and 64 d.v. on both sides, with a negative Rinne, though slightly shortened bone conduction for 256 on the left. Her upper tone limit by Edelman whistle was at 25000 on the right and 21000 on the left. At this time there was no spontaneous nystagmus, though a past pointing error in the lateral vertical plane of 2 inches forwards was present on both sides.

Shortly afterwards she was admitted to the General Hospital, Birmingham, and investigation by Dr. Gilbert Hall, Registrar of the Neurological Department, showed no evidence of any intracranial space occupying lesion, and Mr. Beatson Hird reported her fundus oculi and vision normal. My colleague, Mr. Alan Stammers, at my request, carried out a section of the anterior  $\frac{1}{8}$  of her left auditory nerve in the posterior cranial fossa, using the cerebellar route. No difficulty or complication was encountered ; she made a perfect post-operative recovery and her traumatic nystagmus had almost disappeared a week later.

My chief consideration in asking him to deal with the auditory nerve in this way was firstly to exclude an VIIIth nerve tumour in view of her numerous symptoms, which suggested that more than a labyrinth dysfunction was present ; and secondly because I did not wish to carry out a destructive operation on her left labyrinth through an infected area.

Six months afterwards she reported that her subjective vertigo persisted as before, but that now the attacks of abdominal distress came first, followed by vertigo, while prior to the operation her vertigo appeared first and was followed by abdominal symptoms.

After this I lost sight of her until *March, 1946*, when she was referred to me in Hospital by Dr. Daly of Quinton. She then told me that after her operation 11 years previously her giddiness had not completely disappeared, and she was a little unsteady all the time, especially when she turned to her left. With the passing years there was no change in this, but periods lasting up to three months occurred, when she was very well ; and she noted when her nerves were bad her unsteadiness returned. The attacks of rotary nystagmus and vertigo had never returned.

She remained reasonably well until three months earlier, when after an attack of influenza she experienced a nerve attack starting with a sensation of rotation in her epigastrium ; and now she notes that pressure on her left knee produces vertigo, when external objects move from her left to right, and when she raises her arms she feels giddiness coming again and she has to drop them.

She thinks she is a little deafer in her left ear, and has an intermittent tinnitus " like a low hiss of humming " in her right ear and a " high pitched sound " in her left ear ; these are only noted when she is quiet. There is no paracusis.

Examination showed congested upper respiratory membranes, a tonsil remains, while in her ears there was no further change in the drumheads.

Her tuning fork tests showed her able to hear the range between 2048 and 64 d.v. on both sides.

## Clinical Record

The differential 256 test by A C showed Weber referred to the left  
Bone conduction shortened on the right side and equal to mine on the left  
Rinne positive on the right and negative on the left side  
Her A C Audiogram shows a high tone dip on both sides  
There was no spontaneous nystagmus

From these findings I conclude that her hearing level on the left side has been maintained during the past eleven years

I would like to express my thanks and appreciation to Dr Gilbert Hall and Mr Beatson Hird and congratulate my colleague Professor F A R Stammers on the result of the operation

# SOCIETIES' PROCEEDINGS

## ROYAL SOCIETY OF MEDICINE—SECTION OF OTOLOGY

February 1st, 1946

*President*—A. J. WRIGHT, F.R.C.S.

### Discussion on War Deafness and the Care of Deafened Ex-Servicemen

W. I. DAGGETT

The subject chosen for the consideration of this section today is one that requires careful handling. The field is a large one and, if the opener tries to cover in detail all aspects of service deafness, there will be no time for discussion. Although there has been abundance of clinical material throughout the war period, it has been quite impossible for army otologists to advance our knowledge of deafness in any revolutionary way. Cases have all too often been seen but once or twice before evacuation; E.N.T. departments have not been equipped for research; whilst record keeping has been so difficult that essential facts have often been lost. From the scientific point there is little to be gleaned from small series of cases examined under such conditions. General impressions may be useful as a spring board for further investigation, but the conclusions drawn from them are not of themselves of permanent value. Despite this, I would like to pay tribute to those otologists who have put on record their findings, for I know only too well what their difficulties have been. Regretfully I must admit that most of what I have to say today amounts to personal impressions, largely unsupported by statistical evidence. No claim whatever is made for original thought or work.

Hundreds of thousands of fighting men have been permanently deafened to some degree during the war, and it is my first purpose briefly to review the types of deafness which were seen by Army otologists. Later, when discussing after care, I propose to solicit the opinion of members regarding percentage disability allowed to deafened service men in accordance with the first schedule of the Royal Warrant.

I cannot confine myself strictly to deafness which started during war service because many recruits were taken in without a proper aural examination. I have seen young otosclerotics whose length of service was just over a year unable to hear a conversational voice at 2 feet. Other cases have appeared for boarding in whom the ravages of chronic suppurative otitis media during childhood have gone unnoticed. Again it was more common than one would suppose to discover total deafness in one ear, the origin of which had obviously preceded army service.

# Royal Society of Medicine

As early as 1941 it was becoming recognized that too many men with incapacitating aural lesions were being accepted, in the fullness of time, referring recruits to otologists came into being and thus has proved most successful

The scale of pension allowable to patients whose disability was not spotted before enlistment raises a problem which will be referred to later

Every kind of deafness was met with by army otologists at one time or another even senile deafness, therefore a detailed analysis is out of the question I shall omit any description of deafness affecting flying personnel because my experience of this branch of otology has been so limited and because Air Commodore Dickson, who is speaking later, has an unequalled knowledge of the subject

For the sake of convenience I propose to speak of

- 1 Conduction Deafness
- 2 Perception Deafness
- 3 Functional deafness which includes hysteria and malingering

## CONDUCTION DEAFNESS

Acute otitis media resulting from spread of infection along the Eustachian tube was common in the army Except when sufferers were debilitated by prolonged exposure and lack of food it behaved as one would expect, severe residual conduction deafness was noted in a small number of my own cases, but at the time I had never considered any possible connection between this unexpected sequel and the exhibition of sulphonamides

Middle-ear damage resulting from blast has been given much consideration by otologists everywhere, and it is axiomatic that correct treatment of cases in the field and base hospitals was all important Unwarranted interference *ab initio* was a dangerous and pernicious practice never altogether eliminated There are many ex-servicemen who must now take time off work to attend clinics on account of chronic suppurative otitis media which followed syringing or the use of drops immediately after injury

Sometimes in the early days one was tempted to consider lucky those wounded men who were too ill to complain of deafness and too shocked for others to spot their disability at least their ears were left alone McNaughtan<sup>2</sup> before Alamein made a routine examination of 300 men wounded by bursting missiles ten per cent suffered blast injury to the drum he states that in almost every infected case there had been interference by syringing or drops Because it was often impracticable for all seriously wounded men to be examined by an otologist deafness would sometimes not be officially recognized till months later When there was no note of injury on the Field medical card or case history sheet confusion arose when attributability was being assessed by a Medical Board

Rupture of the drum from blast causes conduction deafness which may pass off completely after healing has taken place Undoubtedly however, in quite a high proportion of cases, complete restoration of hearing does not occur because of co existing cochlear damage Suggit<sup>2</sup> (1943) puts this figure at 22 per cent and Collins<sup>3</sup> (1945) at 40 per cent In many cases where



## Societies' Proceedings

there is no associated cochlear damage, loss of hearing following drum rupture is surprisingly small granted that infection does not supervene.

An impression was gained in the first Great War that drum rupture minimized cochlear damage. Guild<sup>4</sup> (1941) considers that this contention is supported by his own animal experiments.

Otosclerosis has been mentioned already and calls for but one comment. Deterioration of hearing is more rapid under war conditions and may be remarkable under the stress of prolonged bombardment and privations.

### PERCEPTION DEAFNESS

Perception deafness resulting from gunfire and explosions is inseparable from modern war, its characteristics are well known. In a then confidential report, now submitted for publication, Murray and Reid<sup>5</sup> in Australia described some interesting experiments carried out upon soldiers exposed to measured gun blast pressures. They found that the amount of internal ear damage a gun was liable to cause runs parallel with the "peak blast pressure". Even small blast pressures caused severe deafness if a sufficient number of rounds were fired. These observers took audiometer readings before and after exposure and noted the high pitch loss which is now familiar to us all, the common "peak loss" between 4096 and 8192 cycles, and the tendency of extension to the lower frequencies which may follow severe exposure. The papers of Suggit<sup>2</sup> (1943), Silcox and Schenk<sup>6</sup> (1944), Collins<sup>3</sup> (1945) and many others also present interesting points in the same subject.

In jungle warfare men with high pitch loss were undoubtedly handicapped in night operations when the snap of a twig or the call of a bird might be of significance.

Because it is agreed that there is no curative treatment, official consideration was constantly being given to prevention. At present there is no satisfactory answer.

Suggit suggested that improved protection for naval gunners might result if tight fitting helmets with telephones were adopted. He pointed to encouraging results which followed their use in aircraft and quoted the work of Dickson, Ewing and Littler<sup>7</sup> (1941). In the army such protection might have been feasible for personnel of fixed coastal defence batteries, but would be otherwise quite impractical. For instance helmets and respirators could not safely be worn together.

Certainly such helmets might have been adopted with advantage for the personnel in engine rooms of M.T.Bs, for serious perception deafness was very common in men so employed. This is not to be wondered at, for three supercharged petrol engines of 1,500 horse power each were packed into a space so small that the noise was unpleasantly loud even before the throttles were opened.

Murray and Reid<sup>5</sup> described their experiments with an ear protector (Protector Ear drum Aust Mark 1) and showed that it was indeed effective, but admitted that, like all efficient devices, it gave rise to a minimum overall 30 decibel loss. They maintained that such protection should be worn, because without it deafness rendered the hearing of orders difficult anyway. They

# Royal Society of Medicine

stated that orders could easily be given in such a way that protected personnel could hear them: I consider that this is questionable.

The protectors described were made of neoprene synthetic rubber, they were hollow except for a single diaphragm of the same material, and the outer surface was stepped, its size conforming to a cross section of the external meatus. It was claimed that, when introduced with the aid of a lubricant consisting of merthiolate in a lanoline base, there was little chance of external otitis. Personally I cannot help thinking that, if such plugs were used in the desert, external otitis would result whatever precautions were taken.

Many men do not consider that they are deaf at all and yet have a characteristic hearing loss above 4096 or even 2048 cycles. Just before I was posted away from my first overseas unit, Major Helme of the Royal Artillery constructed an audiometer out of spare Radar parts. Testing at random personnel from one 3.7 AA gunsite, I found that only one cookhouse worker showed a normal curve. What happens to these men eventually? I have little doubt that when they reach the age of 45 to 50, a great number will be all too conscious of their infirmity. It is impossible to think out any schemes for compensating men with premature presbycusis.

Perception deafness resulting from causes other than gunfire and explosions were not common. I have seen two cases of severe deafness (one virtually complete) which occurred in patients suffering from proved undulant fever.

Persistent deafness following large doses of quinine was seen but once McMahon<sup>8</sup> has recently pointed out the rarity of quinine deafness in the American Army. Undoubtedly the adoption of mepacrine for the suppressive treatment of malaria has been a responsible factor.

I became very interested in perception deafness of an unusual type which affected a large proportion of sufferers from scrub typhus in the North Borneo epidemic of 1944. Major Dimond<sup>9</sup> first drew my attention to the condition and he has written up his findings in nearly 100 cases. Lt-Col Ransome<sup>10</sup> who had been Associate Professor of Medicine at Singapore, told me that in certain epidemics of scrub typhus in Malaya, deafness was well known, but in Napier's latest textbook there is no mention of it as a feature of any single one of the rickettsial diseases.

I examined many of Dimond's cases with him and was convinced of the truth of his contention that perception deafness was a reality and occurred before the disease could be certainly diagnosed. Quinine had been given to some patients before evacuation to base and this confused the picture for a day or two. The extreme apathy characteristic of the disease often rendered examination valueless. Perhaps it is true to say that this same apathy has precluded the recognition of deafness in other epidemics. Complete recovery, which however could not be confirmed by audiometry, took place when the convalescent stage was reached. Dimond suggested that a tuning fork should be considered a most valuable diagnostic instrument in suspected cases of scrub typhus.

At this point I would like to mention that unilateral complete deafness was often missed even by otologists, because hearing tests were performed without adequate masking, and a false negative Rinne was not appreciated.

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Mistakes such as this might mean that men capable of causing disaster could participate in front line jungle warfare.

### FUNCTIONAL DEAFNESS

From my experience in Malta and the M.E.F. I agree with Lumsden<sup>11</sup> (1945) that functional deafness was rare. Collins<sup>3</sup> (1945) has already pointed out that in certain cases men would tend to exaggerate the degree of their deafness; indeed in 1943 this became a troublesome problem in one desert hospital which drew cases from a large base camp holding many low category men. The soldier whose hearing standard was 3 and who was categorized B6, after months of idleness or irritating fatigues became frustrated and depressed because there were not enough useful jobs for B6 men; his hearing loss then became difficult to assess. Frequent audiometer readings to show up inconsistencies were not possible. It was fortunately not very detrimental to the war effort if errors were made and such men were boarded home before they became fixed psychotics.

In India functional deafness assumed serious proportions. In the first large Indian Base Hospital I visited there were no less than 17 cases in one ward. The condition was virtually unknown amongst British troops, and it was not until I had been in the country long enough to learn the bare essentials about Indian life and customs that any line of action could be recommended to higher authority.

May I digress for a moment and remind you that, though the Services recruited from sections of the Indian community which traditionally produce born soldiers, the vastly expanded war time army drew extensively upon illiterates whose intelligence was low and who had no knowledge what the war was about. Because pay was good and food assured, tens of thousands of most unlikely recruits joined up and fought well. There were however many whose nostalgia for village life made them discontented. Thus there became a conflict between individual needs and service requirements and functional illness resulted.

Of the apparently completely deaf men seen at base hospitals there were three main groups.

1. Patients with some demonstrable lesion of the hearing mechanism.
2. Patients with true hysterical deafness.
3. Patients who were malingering.

Group 1 was mostly drawn from troops who had been in action. Some were genuine but a greater number had a hysterical overlay.

Group 2 comprised those who had become unaccountably deaf after some battle (or battle training) incident and had not been dealt with in the early stage.

Group 3 was made up of soldiers who were serving in labour and pioneer battalions as well as those who wished for an excuse to avoid danger and discomfort.

I am quite clear on one point, namely that the true malingerer who was allowed to get away with his deception in the first few brushes with his medical officer invariably assumed what might be called "induced hysteria" which could never be broken.

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There was a well known "routine" amongst Indian malingerers. Some irritant such as the marker nut was applied to the meatus of both ears with a long dirty finger nail, irritation, excoriation and sepsis quickly produced a severe external otitis. The patient would wait till there was free discharge and some periauricular tenderness, then he would assume complete bilateral deafness and report sick. It was easy to disturb the composure of a young R M O who had learned that profound deafness associated with mastoid tenderness and otorrhoea was often a serious condition. There might be delay before a specialist opinion was obtained, and even then inexperienced otologists would let doubts assail them. If such men were admitted to hospital for observation they became confident in their deceit, and subsequent measures to restore hearing rarely succeeded whether a psychiatrist was convened or not. Induced hysteria quickly became a reality and it must be remembered that when this stage is reached patients do not in fact hear.

The Indian would never simulate unilateral deafness. He would squat or stand with downcast eyes looking the picture of misery, he would show no interest in any tests that were being carried out and would avoid looking at the medical officer who was investigating his case. Patients would not acknowledge hearing any sound by air or bone conduction nor would they admit appreciating vibration when low pitch tuning forks were pressed upon the mastoid process. A group of such cases collected together was interesting, no attempt by sign or gesture was made to initiate inter-communication. To surprise such a group attempting to make mutual contact was rare. The medical officer's difficulties, when his only assistant might be an Indian interpreter in sympathy with the sufferer, can be well imagined.

Craig<sup>12</sup> (1945) has stated that it was always possible to differentiate organic perception deafness from hysteria or malingering by a simple cold caloric test. I fear I cannot agree with this view.

The key to rational treatment of all kinds of functional deafness is "early recognition", and this proved extremely difficult in practice. It was too wasteful to post otologists far enough forward for them to collaborate with psychiatrists close to the line and in the advanced rest areas, but only at this level could hysterical states be easily and quickly broken down.

Malingering should have been spotted earlier and more frequently than it was. The condition was virtually unknown in well disciplined units whose medical officers were alive to the "clinical picture" and had the courage to recommend disciplinary action forthwith. In some units on the other hand, malingering assumed epidemic proportions largely as a result of inexperience amongst medical officers, and lack of firmness amongst commanding officers.

## AFTER CARE

It is pathetic to contemplate how little we have to offer deafened soldiers. I have no revolutionary suggestions about the treatment of perception deafness and consider that any comments from me on the subject of lip reading and artificial aids would serve no useful purpose.

In regard to persisting chronic otitis media which may lead to further deterioration of function, I would like to air views which I hold very

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No otologist who has run E.N.T. clinics in Army hospitals can possibly evade the conclusion that the results of treating his cases of chronic otitis media were infinitely better than those in civilian hospitals. The contributions of Banham<sup>13</sup> (1944), Scott Stevenson and Ballantyne<sup>14</sup> (1945) bear out this statement. Banham found that 80 per cent. of all cases responded satisfactorily to careful conservative treatment and that, when the perforation was central, one hundred per cent. became dry. The reason was that painstaking individual attention was possible for every patient.

It seems to me to be the duty of the medical profession to organize E.N.T. services which provide facilities for the regular and efficient toilet of discharging ears by competent men. It is also essential that there should be a minimum of interference with the working hours of patients. Systems which allow seething masses of outpatients to wait hours for some harassed young house surgeon to repeat their drops must be revised and a more efficient plan substituted.

In the Middle East, largely due to the drive and initiative of Lt.-Col. Lumsden, centres were started under otological supervision in which orderlies cleaned out ears. These orderlies were carefully trained and became alert, interested and useful men, proud of their head mirrors and clean hands. This system worked better than anyone could hope, and there seems no valid reason why nurses should not be trained for similar work in comparable civilian centres.

## COMPENSATION

I suggest that the opinion of members of this section regarding the existing scale of deafness pensions might be of interest to the Ministry of Pensions.

These are the rules laid down in the first schedule of the Royal Warrant :—

"Each ear should first be tested separately, the other being blocked and the examiner placed at the side of the ear being tested. Both ears, used together, should then be tested with the examiner facing the patient, who should have his eyes closed. The degree of hearing should be recorded for (1) each ear separately, and (2) both together, according to the following scale. Assessment should be based on the Grade attained using both ears together; the percentage assessment suggested as appropriate to the Grade thus attained is given in the last column :—

Grade	Degree of Hearing attained	Assessment for both ears used together
0	Total deafness .. ..	100%
1	Shout not beyond 3 feet .. ..	80%
2	Conversational voice not over 1 foot	60%
3	Conversational voice not over 3 feet	40%
4	Conversational voice not over 6 feet	20%
5	Conversational voice not over 9 feet	
	(a) One ear totally deaf .. ..	20%
	(b) Otherwise .. ..	less than 20%

A case in which the right ear attained Grade 4, the left ear Grade 2, and both ears together Grade 3 should therefore be recorded thus :—

R : 4. L : 2. R+L : 3. Assessment :—40%.

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The assessments given above apply to the deafness itself, apart from complications such as vertigo, tinnitus or chronic suppuration. In so far as tinnitus may increase deafness it will thereby affect the assessment by lowering the standard of hearing. It may also interfere with sleep, and there may be justification for an addition to the assessment on that account. Vertigo should be assessed on its incapacitating effect and association with other diseases."

I will make but three comments

1 There is no mention in these rules about differentiating patients whose hearing capacity is markedly increased by an instrument from those who are not helped by such means

2 It has been suggested that those whose pre-war training enables them to earn good money whether deaf or not should be assessed differently from those who have not this advantage. Personally I consider that such differentiation is not feasible and would only give rise to dissatisfaction. If a scheme were worked out on these lines it would be tantamount to a "means test" and therefore intensely unpopular

3 Difficulties can be envisaged when assessing the percentage disability of those hysterical patients already alluded to when their hysterical state cannot be broken down. These difficulties must of course be overcome by psychiatrists armed with an otological report. Such cases will be judged with due attention to emotional instability both before and during service. Doubtless some mistakes will be made, but it should be rare for a case of hysterical deafness to be awarded 100 per cent disability

Lastly I must refer back to those deafened soldiers whose affliction antedated enlistment and yet was undiscovered. Such men are entitled to pensions even when otological opinion states that their disability neither resulted from nor was aggravated by war service. In the Ministry of Pensions instructions for Medical Boards it is clearly stated—"If the disability which led to the member's discharge is not recorded in the medical report made at the commencement of service, it is to be assumed, in the absence of definite evidence to the contrary, not to have been present at that time." This instruction assures justice to those men who reported their deafness and yet were not believed

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eight hours. Deafness up to 1,000 cycles was less than 20 decibels. This increased to over 70 decibels before 2,000 was reached. The drums were normal.

3. A bomb fell near an A.T.S. girl during a Plymouth air raid in April 1941. She was not unconscious or shocked and the deafness was noticed at once. When I saw her more than four years later the drums were normal and she showed exactly the same audiometer chart as the other cases I have mentioned. There was less than 20 decibels of deafness up to 1,500 cycles. This had increased to *over 70 decibels before a frequency of 2,000 was reached*. She could hear the conversational voice with ease at 25 feet in a reasonably quiet room but could make nothing of general conversation and she could not hear the telephone bell. This is characteristic of all these cases provided the involvement of the lower frequencies is not too great and shows that a serious disability may be easily missed in the speech test. It is, of course, noted at once on the audiograph.

Now in case I have given you the impression that these gunfire cases at all events offer no difficulties as far as aetiology is concerned, I will quote a fourth case in which the history points as clearly to gunfire as the cause of the deafness as anything we ever get. After a salvo of big guns in Alexandria in 1942, the man found he was deaf. When I saw him over three years later there was a healed linear vertical scar in the lower part of the left drum. Both drums were otherwise normal. The audiometer showed a marked middle-ear deafness, equal in the two ears, with a steep fall below 250. Above this frequency the threshold line ran more or less horizontally up to a frequency of 4,000. Bone conduction was normal and the Rinne was negative.

It is probably in these cases of gunfire deafness more than in any other that we come across another most unhelpful factor. This is individual idiosyncrasy. We see cases which are permanently and even progressively deafened by the most trivial exposure to gunfire. It may be on their first day at the small arms training range. This factor makes it impossible to adopt an arbitrary minimum below which conditions would not be regarded as reasonably probable aetiological factors.

Concussion deafness. In these cases, when other factors can be excluded, the deafness is of the middle-ear type. If there is any selective drop of the threshold line it is in the lower frequencies. By the time we see these cases it is usually impossible to tell if the petrous bone has been directly involved. Often there is a history of bleeding from the ears and occasionally of facial palsy. In some cases there is complete deafness with loss of vestibular response. I am excluding these cases. For the others there seems to be no obvious correlation between the severity of the cranial injury and the resulting deafness. I will quote two cases:

In the first case a motor cyclist had a head on collision. There was an extensive fracture of both skull and jaw and he was unconscious for five days. When I saw him a year later the hearing was practically normal for both ears. There was a history of some deafness and palsy on the left side but these had disappeared.

The second case was an air crash with fractured base and other injuries. He was unconscious for ten days. When I saw him three years later the

drums were normal and there was practically no deafness. On the audiometer the threshold line was approximately horizontal in the region of ten decibels in both ears and no deafness could be detected by the speech test.

These cases stand in marked contrast with those that show a marked middle ear deafness following quite trivial blows on the head without fracture or even scalp wound.

**Blast** The visible damage in these cases varies from a linear tear which quickly heals to a large jagged perforation and even displacement of the ossicles.

When no infection has been added to the injury these cases can usually be readily recognized as of traumatic origin even when seen long after the incident. When sepsis has supervened this diagnosis may be impossible to make by inspection.

Some of these blast cases show severe deafness with the steep fall for the higher frequencies characteristic of gunfire deafness. Here the noise of the explosion may be taking a hand in the clinical picture or they may be cases in which the blast has involved the lower portion of the cochlea contents. Apart from these latter cases, which are in a great minority, the astonishing thing is the slight degree of deafness which may be present even with extensive damage to the middle-ear contents. This is in harmony with what we so often see in chronic aural sepsis. I will quote one such case. An officer stepped on a mine. He lost a leg and an eye and both drums showed large irregular and obviously traumatic perforations. There was no detectable deafness in either ear for speech at 25 feet.

I have said nothing so far about those cases in which there is no organic lesion to account for the deafness. Cases, that is to say, of functional, hysterical or psychogenic deafness. These terms, I take it for I must confess that I am completely out of my depth here, all mean that these cases have on the one hand no organic lesion to account for the deafness and on the other no conscious responsibility for the deafness present. They have nothing in common with the deliberate malingerer except the absence of an organic lesion.

I have adopted a working rule that when a case shows a constant graph in the audiometer test these psychogenic factors can be ruled out and an organic lesion can be assumed to be present. One capable of recovery in many cases but in the late cases usually seen at the Pensions Clinics probably permanent. It is possible that this may occasionally lead to an error of diagnosis and a functional case be assumed to have an organic lesion. Both the treatment and the prognosis will be involved in the error, but in so far as the deafness is outside the man's conscious control, that is to say if the wilful malingerer is eliminated, the deafness still remains the man's disablement.

I would like to remind you, in conclusion, that the Ministry of Pensions is not engaged in original research. Unlike the research worker it cannot wait till its decisions rest on an unassailable basis of scientific fact. If it did so many of these men would have to wait a long time for their pensions. The important thing is that the Ministry's decisions should be arrived at promptly and with the least possible risk of injustice to the men. As I have already said when a doubt exists the benefit of it is given to the man.



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## Rehabilitation of Deafened Service Personnel

Air-Commodore E. D. D. DICKSON

Deafened service personnel can be roughly divided into three categories:

1. Those who had some hearing loss prior to joining up and whose defect was passed unnoticed and was therefore not recorded in their official documents.
2. Those with some hearing defect which has progressively become worse or has been aggravated through service.
3. Those whose disability is attributable to service and has been caused by exposure to gunfire, noise, H.E., or flying.

The provisions made for rehabilitating these service cases is far from satisfactory. No organized scheme is available for a systematic course in lip reading and for providing a hearing aid under expert medical supervision. By the latter I mean an otologist with a thorough and intimate knowledge of audiometry, some understanding of hearing aids and an appreciation of the problems of rehabilitation. Within the service there is no provision for the rehabilitation of deafened service personnel, as it is considered to be the responsibility of the Ministry of Pensions to organize such comprehensive scheme, particularly for those cases whose disability is attributable to or aggravated by service. Cases whose disability does not come under this category have either to defray their own expenses or depend on the help of some charitable organization.

At the close of the Lords' Debate of Hearing Aids on 14th March, 1945, H.M. Government accepted a motion that otological clinics should be set up as part of any national scheme for the rehabilitation of deafened ex-servicemen. Reference is here made to three centres of rehabilitation already operating in the U.S.A. The essential features of these is that patients are hospitalized and there instruction in lip reading is co-ordinated with the supply of hearing aids and also when necessary with occupational guidance and training and psychiatric treatment.

At one of these centres, Deshon General Hospital, Butler, Pennsylvania, since November 1943 when the service for the hard of hearing was established, 824 patients have been admitted for rehabilitation. A survey of the first 580 cases studied revealed that 73 per cent. had loss of varying degrees before entering the service and 27 per cent. of the patients developed the deficiency as the result of an incident occurring in the service. Aggravation by service was conceded in 10 per cent. of those where hearing defect was present on enlistment.

It is understood that in this country the Ministry of Pensions would prefer treatment within the service. Its postponement after patients have been discharged from the service and returned to their homes makes uniformity and co-ordination of different forms of treatment impracticable. The only clinic in this country for the deaf with facilities for educational treatment and for tests of hearing aids, as well as tests of the capacity of patients to hear speech, is in Manchester under the charge of Dr. E. W. Ewing. It combines facilities for testing the physical characteristics of hearing aids and recommending them to patients after pure tone and speech audiometry and provision

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for instruction in lip reading. All deafened and hard of hearing patients need training in lip reading. Those who can be helped by the use of an aid benefit greatly from instruction about application, capacity, use and management. Many deaf patients for whom a hearing aid has been considered unsuitable in the past are found to do well when taught to combine an aid with lip reading. Extensive experimental evidence is available that the majority of patients follow speech more accurately when lip reading and listening with an aid simultaneously than when relying on either of these means of help separately. This system of educational treatment has enabled many patients to retain normal employment whilst others who have been disabled by marked loss of hearing have returned to suitable work after training. Service personnel whose disability is severe will require occupational training in order to re-establish themselves in civil employment.

It is suggested that the present resources of the Department of Otorhinolaryngology of the Central Medical Establishment of the R A F could be utilized in a directing and consulting capacity making full use of the Acoustics Laboratory which is equipped with testing apparatus and staffed by a phonetics expert, a physicist and technicians all accustomed to aural problems. In drawing up the scope and objectives of the rehabilitation centre close collaboration would have been maintained with Dr Ewing's Department in Manchester and a liaison with the three Committees of the M R C now investigating the medical and educational treatment of deafness. Each patient's capacity to benefit from a hearing aid would be determined by trial and this could be as lengthy as is required to accustom the patient to its use and maintenance and for the otological staff to approve its value. It is suggested that all patients invalided from the service on account of deafness should be posted to a rehabilitation centre for assessment of the disability and the amount of training required.

Attention should be paid to the future occupation, auditory requirements, prognosis and intelligence of the patient when the optimum improvement had been attained. The attention of the Ministry of Labour would require to be directed to the possibilities of employment in cases requiring it.

## THE REHABILITATION CENTRES

At the rehabilitation centres lip reading would be taught in classes but individual instruction is needed in some cases especially in severe or total deafness of sudden onset. In the more advanced stages of training actual practice and informal group discussions are extremely beneficial. Lessons in lip reading and hearing aid instruction can be combined. When individual instruction is necessary the time per day would vary with the needs of the patient and severity of the case. In the U S A scheme most cases receive one or two thirty minute periods per day either in individual or group classes or both. Others report once or twice a week for rechecking. The overall length of treatment is likely to be 2½ months—that is the period of hospitalization. If it is impossible during this period to eliminate all problems then recommendation and practice material are given to the patient when he leaves hospital. The results reported by the U S A centre have been satisfactory.

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Progress and improvement depend primarily upon the ability and desire of the patients to apply themselves.

An important factor is arousing the enthusiasm and interest of the patients in cheerful surroundings and occupation available through the day. The success depends largely on the choice of personnel running the centre and facilities for occupational therapy should be on a comprehensive scale.

The personnel considered necessary for operating a rehabilitation centre would be as follows :

1. An otologist to be in charge of the centre, to be responsible for the clinical work and co-ordinate the activities of the centre.

2. A full time fully qualified lip reading instructor, with some understanding of hearing aids.

3. A physicist in charge of an acoustics laboratory. Laboratory facilities are considered a most essential part of any such scheme. Two technicians, one with a knowledge of audiometry. He would assist the otologist and the lip reading instructor with the hearing aids. An electrical mechanic to repair and maintain the testing electrical apparatus and hearing aids.

4. A part time neuropsychiatrist (psychologist).

5. A welfare worker who could maintain liaison with the Ministry of Labour, the charitable institutions for the deaf and patients' families. He or she would also organize entertainments, discussion groups, etc. and learn the patients' individual problems. He or she would be a most important member of the staff and the success of the scheme will largely depend on the choice of the right individual for the post.

6. A reputable firm of hearing aid manufacturers who will work in the closest liaison with the medical and technical staff of the centres.

In a certain number of instances an attempt has been made by the R.A.F. to help some of the most deserving cases, particularly when the cause has been established to be attributable to service hazards. Arrangements have been made for a course of training in lip reading and a hearing aid was supplied—the expenses being defrayed from service funds. We have facilities for fully investigating every case and for testing the performance and qualities of any hearing aid supplied. Only after we are satisfied that it fully meets the patient's requirements is sanction given for its purchase. We have had the help and co-operation of a reputable firm of hearing aid manufacturers. They have loaned their aids on an extended trial and provided full service before and after purchase. Cases whose disability is not attributable to or aggravated by service have also been advised on the most suitable type of aid and this firm has generously given as much as 40 per cent. discount to deserving cases. Again approval for its purchase rests with us.

Unfortunately there are still many ill-advised cases who are being exploited by unscrupulous firms and being sold useless hearing aids for fantastic prices. I have personal knowledge of such cases. They have little or no redress except perhaps being sold a more expensive instrument. It is our duty to protect these service patients.

It must be realized that once a service case has been invalided or demobilized it is not easy to institute a comprehensive course of rehabilitation such as we envisaged and which has been put into operation in the U.S.A. unless some

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form of hospitalization is adopted. To issue a hearing aid without some form of rehabilitation is a waste of money.

THE PRESIDENT said that the three openers had put very ably the various sides of this difficult problem. Personally he had listened to them with great interest, and he felt, as a result, a very humble man. Some faults they seemed to commit war by war, generation by generation. He was old enough to remember that in the first world war they suffered from the fact that men were recruited without sufficient preliminary examination. That fault they had unfortunately committed again. He was old enough also to remember that in the first world war the greatest risk to the damaged ear was the doctor, and that again, he was afraid, was one of the risks that the damaged ear had had to face in this war. During the first world war he had for a time the care of a very large number of cases of middle-ear suppuration in hospital, with the advantage of day-to-day care by trained V A D s, and at that time he was struck, as many others were, by the extraordinarily good results obtained by detailed routine care of these cases. Twenty years or more had passed, and the circle was now completed. Once more they were saying that in the next war they must really examine the men before they were called up, and in peace time must really take the trouble to organize routine conservative treatment for cases of suppurating ears.

MR. R. G. MACBETH said that it had been his good fortune to visit the Naval Hospital at Philadelphia 15 months previously. This hospital was devoted largely to the rehabilitation of all types of naval and marine personnel. It might be interesting if he outlined the manner in which a deafened man was dealt with in that hospital. He returned from his theatre of war and was immediately given a month's leave. Then he was directed to enter this hospital. At the hospital he was examined carefully by skilled otologists and if there was any physical disease, whether attributable to the war effort or not, this was treated. He was assessed from the point of view of his hearing, audiograms were taken, a general physical check-up was made, and he was seen also by a psychiatrist. If it were thought necessary he was then fitted with a hearing aid, or given lip-reading instruction, or both, all within the hospital. He was then placed in a ward with men suffering from various disabilities, other than deafness, and therefore there was little likelihood that he would feel particularly sorry for himself.

Each morning the man would be given instruction on various matters, as, for example, how later on to draw his pension, what insurance schemes were available, and so on. An investigation was made as to what his trade, or profession might have been and whether or not this occupation was suitable for him on his return to civil life. If the occupation were not suitable for a deafened person, attempts were made to find him one more appropriate to his disability in his home town. The afternoon and the rest of the day was free for him to do what he wished within the framework of a naval organization, and the curfew in that particular hospital did not sound until midnight. Thus, although he had certain duties in the morning, ranked as parades, he had nothing to do for the rest of the day.

These men could be seen wearing their hearing-aids in uniform and taking part in ordinary activities, such as attending dances, the cinema, and even

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concerts in the evening. One felt that the morale was very high, and that these men were going to be useful citizens. They realized that although they had lost something in its service, the State was not unmindful of them. Their manner and attitude was in striking contrast to the disgruntled behaviour met among those men in this country referred, possibly months after discharge, by the Ministry of Pensions for an opinion on their deafness.

MR. SCOTT STEVENSON said that he had been rather shocked to hear from Mr. Chubb that the audiometers used by the Ministry of Pensions went up only to 4,000 cycles. He hoped that would be altered in the near future, otherwise there would be some cases of cochlear deafness which would not get a square deal, as their hearing loss would show between 4,000 and 8,000 cycles. In some occupations the deafened man could carry on very well, but in others he was severely handicapped, but apparently the Ministry of Pensions could not take that into consideration. He had the impression that a man with chronic middle-ear suppuration but who had good hearing did not get any compensation from the Ministry of Pensions; yet he did not think any of them would pass such a man with chronic middle-ear suppuration for life insurance. Such a man was under a disability which might possibly become a serious one. Another point concerned the men whose deafness, they were told, underwent a natural increase. Cases had been turned down for pension on the ground that the increase of deafness was only natural. This depended entirely on the opinion of the otologist and otologists would differ on this point. It was wrong that any man should be turned down by the Ministry of Pensions merely on account of a so-called natural increase of deafness. He was glad to hear that the R.A.F. were providing hearing-aids, but these should certainly be provided at the expense of the Ministry of Pensions, and he understood that that had been promised by the Minister.

MR. C. HAMBLÉN-THOMAS said there was not a sufficient number of trained technicians, including nurses, to deal with all these cases. The difficulty was to get patients treated by other than specialists. They had the specialists, but when it came to the carrying out of after-treatment it was difficult to get this done adequately. Something should be arranged whereby technicians and nursing staff were sufficiently trained to carry out the treatment which might be required. He had also found that out-patient treatment was not as satisfactory as in-patient. Unfortunately, in this country we were short of funds for this purpose, whereas over in America they had an unlimited amount of money. In this country it was known what the treatment should be but the trained people to carry it out satisfactorily were not forthcoming.

DR. SIMSON HALL said that he had noticed in examining naval personnel on several occasions that they suffered from blast deafness. He wondered whether there had been any research on the causation of nerve deafness by bone conduction. They had heard in the course of that discussion that experiments had been carried out with helmets and suchlike, but had any experiments been done on the use of sponge-rubber soles to the boots in order to avoid the transmission of concussion through the feet?

MR. CHUBB, in replying on the discussion, said that although he had been associated with "Pensions" since the end of the last war, he had not occupied

# Royal Society of Medicine

any administrative position When the recent war became inevitable he had suggested to the Ministry that recruiting boards should be equipped to make satisfactory hearing tests, and that the Pensions Clinics should be provided with Audiometers The latter suggestion was adopted, but the former proved to be impossible It was a matter for regret that these Audiometers only registered to a frequency of 4,000 Both this and the difficulty of keeping these instruments properly calibrated was largely due to war conditions

As for the extract from the Royal Warrant mentioned by Mr Daggett He had protested against it ever since it had appeared in print He understood that a small committee had now been appointed to revise it One obvious fault was that the man with normal hearing in one ear, and complete deafness in the other, actually got a higher pension than the man who could only hear conversational voice with both ears at nine feet The former could hear every word from the Gallery while the latter would have to pay for Orchestra Stalls and then miss half of it

He agreed that there was often an apparent contradiction between the results of the Audiometer and the speech tests This was partly due to distortion, as in nerve deafness and partly to a growing loss of instinctive attention, and with this a loss of familiarity with the sounds of speech It should not be forgotten that the speech test was on the ability to *understand* speech whereas in the audiometer test it was the recognition of a broken silence To a large extent the Pensioner's disablement was determined by his ability to hear *and understand* the spoken voice under ordinary conditions

Speakers had referred to the dangers of inept treatment of the discharging ear He mentioned that an army Medical Officer of high rank circulated to his medical officers printed instructions to the effect that the only efficient treatment in these cases was by the syringe He had reported this to the appropriate authorities and hoped that the Officer concerned had been suitably dealt with

As for hearing "Aids" It was the practice of the Ministry as far as this was possible, to deal with firms of whose efficiency they had had long experience This was, however subject to any definite predilection expressed by the pensioner Efficiency in Hearing Aids was improving extremely rapidly, but they had not yet reached the point of being able to prescribe an Aid to suit the individual case In practice it came to testing the pensioner with different Aids and this was what was done

MR DAGGETT replied that he was not aware of any research with rubber-soled boots on the lines suggested by Dr Simson Hall Certainly none had been done in the Army

AIR COMMODORE DICKSON also in reply said that he agreed with Dr Scott Stevenson that if one was running the centres one should utilize the services of one or two of these firms

His meaning of "hospitalization" was residence in a centre where the surroundings were cheerful

## OBITUARY

### DR. PETER MCBRIDE

THE recent death of Dr. Peter McBride at the age of 92 has severed the last remaining living link with the early days of laryngology in Edinburgh. Born in Hamburg, Peter McBride was educated at Clifton College and Edinburgh University. After qualifying M.B. in 1876 he served as House Physician in the Royal Infirmary and became M.D. in 1881. He was elected a Fellow of the Royal College of Physicians in 1880. Unlike otology, which was a surgical speciality from the first, laryngology was a child of medicine and the laryngologist was a physician.

McBride amplified his studies in Vienna, then the medical post-graduate teaching centre of the world and on his return to Edinburgh he was appointed Surgeon to the Eye, Ear and Throat Infirmary in Cambridge Street and Lecturer on Diseases of the Ear, Nose and Throat in the extramural school of the Royal Colleges. Otology and laryngology were studied and practised as separate subjects in London, Glasgow and elsewhere, but in Edinburgh they were united from the first.

In 1883 a department consisting of one small room in which patients were seen twice a week was allotted to the speciality in the Royal Infirmary, and in 1897 the University established a lectureship on diseases of the Ear, Nose and Throat. Dr. McBride was the first to hold each of those appointments, and it was largely owing to his hard work and initiative that a fully equipped department was established before his retirement in 1903. His writing was clear and concise and it is not surprising that his text book, *Diseases of the Throat, Nose and Ear*, originally published in 1891 retained its popularity through three editions. In the preface to that work, one may find a statement which reveals the logical mind of the writer: "All drawings of instruments have been omitted . . . They are unnecessary for the simple reason that the practitioner must possess the means of operating before he proceeds to operate".

Dr. McBride's ability won for him many honours; in 1883 he became a Fellow of the Royal Society of Edinburgh, he was President of the Laryngological Society of London, of the Otological Section of the Royal Society of Medicine, and of the Section of Otology and Laryngology at the British Medical Association Meetings; he was also elected an Honorary Member of the Scottish Otological and Laryngological Society. In 1913 he delivered the Semon lecture at the University of London. On retiring from practice in 1910 he went to live in Yorkshire, at first at Harrogate and latterly at York. There, so long as health and energy permitted, he indulged his favourite sport of hunting. Throughout his life he took a keen interest in all sports and games. His years of retirement were also employed in

## Obituary

writing interesting contributions to philosophy and psychology. Perhaps the most popular of those works are his essay entitled *Psycho-analysis Analysed* (1924) and his later *Philosophy of Sport* (1932).

Peter McBride was a charming companion and it was a great pleasure for old friends to renew acquaintance with him during his frequent visits to Edinburgh after his retirement. It was characteristic of him that during the war of 1914-1918 he returned to voluntary work as laryngologist at the 2nd Scottish General Hospital under Dr. Logan Turner who had formerly been his assistant. Endowed with a rich fund of humour, he was an excellent raconteur. At the close of his long and useful life we honour the memory of this doughty pioneer of laryngology.

D.G.





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## THE NATURE OF THE VESTIBULAR STIMULUS

By L. B. W. JONGKEES and J. J. GROEN (Utrecht)\*

Up to the present otologists were accustomed to divide the stimuli, which act upon the vestibular organ, into dynamic and static ones. Besides these, reactions caused by the centrifugal force are known. Thus we have

- (1) dynamic stimuli
  - (a) angular accelerations
  - (b) linear accelerations in progressive movements
- (2) static stimuli the action of gravity
- (3) stimuli caused by the centrifugal force (Huijzinga<sup>1</sup>)

The reflexes on dynamic stimulation are thought to be caused by movement, the static (tonic) reflexes by a change in the position of the head relative to the direction of the force of gravity.

"The latter are reflexes (Magnus and de Kleyn<sup>2</sup>), which last as long as a certain position of the head is maintained. The dynamic reflexes do not depend on position and are found solely when the head resp. the labyrinths are moved, they are always of short duration in comparison with the static reflexes."

Most investigations on this subject, especially those of experimental physiologists, are based on this difference and the open question about the function of the otoliths (especially the saccule) gives rise every time to the distinction between static and dynamic reflexes.

For instance Werner<sup>3</sup> states that the movement reflexes may be attributed to a function of the saccule, but all static reflexes should certainly be localized in the utricle.

The experiments with destruction of the saccule or with the throwing

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Director Prof. A. A. J. van Egmond.

off of the otoliths by the centrifugal force led to the discovery of differences between dynamic and static reactions, though the conclusions from the results of these investigations were contradictory.

Many experimenters observed the disappearance of the static reflexes after the throwing off of the otoliths, whereas the movement reflexes persist.

On the other hand de Kleyn and Versteegh<sup>4</sup> were still able to produce static reflexes as well as dynamic ones after total removal of the otolith membranes. However, they localize the origin of the dynamic reflexes in the canal system. Huizinga<sup>1</sup> observed the disappearance of the compensatory eye-positions (a static reflex) after destruction of the saccule in pigeons, but Hasagawa<sup>5</sup> noticed the absence of movement reflexes in the dorso-ventral direction after the removing of the saccule of frogs. But there are other authors who do not accept such a strict differentiation between dynamic and static reflexes. Every variation in a static reflex may be understood as a dynamic action, according to Huizinga<sup>6</sup>.

Wojatschek<sup>7</sup> remarks that in alterations of the position of the head the action of gravity is measured. But nowhere in literature could we find any explicit statement regarding the essence of the question, namely that *no fundamental difference between dynamic and static stimuli exists*.

This so-called difference is only apparent and does not exist from a mechanical standpoint.

Let a well-known example of Einstein make this clear. Suppose a person finds himself in a cage somewhere in our universe, beyond the gravitational range of influence of any celestial body. The cage is supposed to possess no acceleration relative to the average stellar matter. Then for him no gravity will exist. In this cage everything will float, the otoliths will not exert any pressure on the maculae. Now suppose we give to this cage an acceleration of  $1,000 \text{ cm./sec}^2$ . From this moment in a mechanical way everything is for the inhabitant of the cage as if he were back on earth. The objects will fall, the test person will stay on the floor (that is that wall of the cage which lies at the side from which the acceleration is pointed within the cage) and the otoliths will again press on their bottom layer. In this way Einstein elucidates the meaning of his statement, that a body in the field of gravity of the earth finds itself in a field of acceleration of  $1,000 \text{ cm./sec}^2$ . It is absolutely the same for this body from a mechanical point of view to be either in the field of gravity of the earth or to be moved outside this field with a linear acceleration of the magnitude of the acceleration of gravity. The centrifugal force has just the same character. The action of an accelerated movement in which the acceleration is as great as the acceleration of the centrifugal force is mechanically identical with the action of

## The Nature of the Vestibular Stimulus

this force It must be kept in mind however that the direction of the replacing gravitation or centrifugal force is just opposite to the direction of the replaced acceleration Already Newton in his law of inertia expressed the same idea about the relationship of force and acceleration

No measuring instrument, however fine, can distinguish between a field of gravitation (i.e. a field of forces caused by gravity) or a field of forces caused by centrifugal force and a field of forces (of inertia) caused by an accelerated movement of the same magnitude and opposite direction This is not a result of the practical inadequacy of the instruments, but of the essential identity of all three In the same way it must be impossible for the measuring device in the human body wherever this organ may be located, to distinguish between the action of gravity, of the centrifugal force, or of the force of inertia caused by a linear accelerated movement Solely a distinction in a quantitative sense is possible, i.e., duration, magnitude and direction of the acting force Because it is necessary to know the magnitude of the mass to be able to calculate the magnitude of a force, in quantitative experiments on living beings the use of accelerations is preferable The magnitude of the mass of the parts of the labyrinth is not exactly known

In all those cases the stimulus for the sense organ is the linear acceleration It is absolutely groundless and confusing to distinguish between different forms in which the linear acceleration shows itself

A real mistake is made when one distinguishes between static and dynamic stimuli in the sense that the two could be perceived by different organs as qualitatively different influences At most a quantitative difference is to be observed Always the field of gravitation is present and exerts its influence on all beings human and animal This is exactly one of the difficulties in the research of the influence of linear accelerations on the sense of equilibrium

It is impossible for that reason to examine this organ in the absence of the adequate stimulus, i.e., the acceleration of the force of gravitation Such an experiment would be possible only during the free fall This explains why the so called static reflexes continue as long as the position of the head remains unaltered In this case the field of acceleration does not change, therefore the stimulus remains the same both in magnitude and direction

Those mechanical considerations force us to make the division of the labyrinth reflexes in another way than was usually done up till now We may divide them as follows

- (1) Reflexes and sensations caused by rotational accelerations
- (2) Reflexes and sensations caused by linear accelerations (in gravity, centrifugal force, and linear accelerated movements)

All reflexes and sensations in one group must be perceived by the same sense organ or eventually the same sense organs

Through which organ is the stimulus perceived?

Is it possible that the same organ perceives both the linear and the rotational acceleration?

For a long time the physiological stimulus for the semicircular canals was known to be the rotational acceleration (Mach<sup>8</sup>, van Rossum<sup>9</sup>). The calculations of Gaede<sup>10</sup> and Schmalz<sup>11</sup> and the experiments of Steinhausen<sup>12</sup> have proved this beyond doubt. Nevertheless this truth is not yet quite appreciated by every investigator. Many of them still mention angular velocity instead of angular acceleration in their publications. Even in 1932, Dorcus<sup>13</sup> still takes the trouble to show that rotating at a constant angular velocity even for weeks has no influence at all on his test animals.

The question through which organ linear accelerations are perceived is not solved so uniformly.

On one side the otoliths or the utricle alone are held responsible (Werner<sup>3</sup>), but other investigators think the semicircular canals the perceiving organs for linear accelerations.

Ter Braak<sup>14</sup> opines that linear accelerations may be perceived by a displacement of the cupula in the semicircular canals as a result of differences in specific gravity of cupula and endolymph. Others think that a displacement of the membranous labyrinth in its bony cover (Lorente de Nò<sup>15</sup>) or a current of the endolymph in the direction of the endolymphatic duct (Magnus and de Kleyn<sup>16</sup>) might possibly give a stimulation of the vestibular organ by linear accelerations.

So theoretically it is thought possible that both angular and linear accelerations are perceived by one and the same organ.

However, it can be proved that this is not the case and so the above-mentioned theories cannot be true. If we try to realize how an organ must be built in order to perceive both linear and angular accelerations we find that it must satisfy the following requirements:

- (1) There must be two of these organs ;
- (2) both of them must be divided in a positive and a negative part (fig. 1) (not anatomically but functionally).

If a linear acceleration acts (Fig. 1A), both similar parts of the organs will be stimulated. By an angular acceleration with centre D. the dissimilar parts of the organs will be stimulated. This combination of stimuli will be experienced as a rotation in the latter case and as a change in position in the former case. All this is perfectly within the range of possibility. The brain has to solve more difficult puzzles than the disentanglement of these two kinds of stimulation.

But if one of those organs is lost (f.i. by a labyrinthitis) it should be impossible to distinguish between linear and angular accelerations. This turns out to be not the case, as we could prove repeatedly.

# The Nature of the Vestibular Stimulus

But there is still another proof that it is impossible for one sense organ to perceive both kinds of stimuli. This proof is found in the physical properties of such an organ, in fact the indication time. Every measuring device, in case the organ  $o_1$  and  $o_2$ , must be built in the following way to be able to perceive acceleration ( $K=ma$ )

A mass is elastically connected to the accelerated system. One of the physical properties of measuring devices of this kind is the indication time, that is the period of time in which the maximal effect (i.e. the sensation) is reached, if the system is exposed to a constant stimulus.

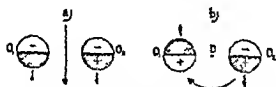


Fig. 1

Fig. 1 indicates the action of a linear (1A) and an angular (1B) acceleration on a hypothetical acceleration both

(black)

or the time the system needs to return to the zero point from a stimulated position, if the stimulation is suddenly stopped\*

If one organ perceives both linear and angular accelerations, the indication time must be the same in both instances. As a matter of fact this is not true. A test person who is subjected to an angular acceleration on a rotating chair has the maximal sensation of rotation not until after many seconds (cf. Steinhausen<sup>1</sup>). In ten cases with our test persons we found an average of 43 sec. varying from 27 sec. to 69 sec. Until that time the person sensed an increasing rotation, after that the sensation remained constant in intensity. For different accelerations ( $0.5^\circ - 2^\circ/\text{sec}^2$ ) this time is very constant for each test person. Probably this indication time is somewhat on the low side because in our rotating chair the acceleration decreases a little at a high angular velocity. On the other hand the indication time for linear accelerations is of the order of magnitude of 0.1 to 0.05 seconds (von Békésy<sup>17</sup>). We could ourselves corroborate this magnitude in experiments with the parallel swing in many test subjects.

There is, moreover, a striking difference in the duration of the after-sensations as a result of either linear or angular accelerations.

The sudden stopping of a rotating chair gives rise to after-sensations of a duration of 30-60 seconds, the sudden stopping of a linear movement gives rise to a very short sensation of change in position. These two values lie very far apart by a factor 300 or even more.

\* One should not confound the indication time and the reaction time of the organ, the latter may be short even if the former is long as is the case here.

Even physiologically this gap cannot be bridged. This is the proof that at least two different organs are necessary to explain the phenomena known up till now.

On account of A: the persistence of the power of discrimination between linear and angular accelerations, also after destruction of one labyrinth, and on account of B: the difference in indication time for the two kinds of acceleration, we are obliged to reject the views of ter Braak, Magnus and de Kley and Lorente de Nò.

Thus on the ground of theoretical considerations, we conclude, that only two different kinds of stimuli are acting on the vestibular organ: i.e., linear acceleration and angular acceleration. The next conclusion is that these two different stimuli are necessarily perceived by two different organs.

It is still our task to demonstrate that indeed the various forms in which the linear accelerations are offered to us have the same effect on sensations and reflexes of the animal or human being under observation.

### Experiments with linear accelerations

We will now investigate what phenomena (sensations and reflexes) are produced in man or animal through the action of linear acceleration. We know the compensatory eye-positions, the labyrinthine righting reflexes, reflexes on muscular tonus, phenomena of the vertical motion, reactions on linear accelerated movements (lift-reaction, "Sprungbereitschaft", the spreading reaction, neurovegetative reactions and sensations. A survey is given by Tenaglia<sup>18</sup>).

About the sensations, only a few communications are published. Fischer<sup>19</sup> and his school and some others noticed that their test persons had a sensation of inclining backwards when they were rotated with constant angular velocity, owing to the action of the centrifugal force. Wojatschek<sup>7</sup> has made circumstantial investigations on the parallel swing and could give his test persons a feeling of seasickness in that way. We examined our test persons in experiments on the parallel swing and on the rotating chair at constant angular velocity.

The accelerations which are created on the parallel swing are best produced in a diagram (Fig. 2). The vertical linear accelerations which accompany the horizontal accelerations are so small in comparison to the latter that they were neglected for simplicity. This is permissible because they stay below the level of minimal perceptibility, and therefore will not influence the course of events.

In swinging, the linear acceleration on the body has the character of a sine. In the zero-position the velocity is maximal, the acceleration is zero. In the extreme positions the velocity is zero, the acceleration or deceleration is maximal. A person on this swing observing his sensations,

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feels an unsteady backward and forward movement, but besides this a definite sensation of alteration in his position

If the swing, with a test person lying on it, is moved in the direction of the test person's head, he has the impression that his head is lowered and his feet are rising. If he is moved in the direction of his feet the sensation is just the reverse. In all other positions of the body similar phenomena were observed (Fig 2). The explanation of these sensations

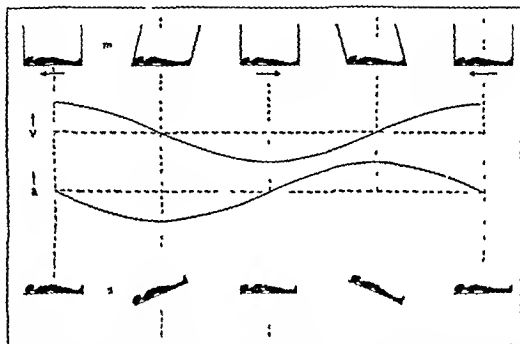


FIG 2

Scheme of the place movement and acceleration of the parallel swing with the subjective position of the test person

(m) movement

(v) velocity

(a) acceleration

(s) sensation

is easily given from an analysis of the mechanical forces acting on the otolith apparatus

Let us consider for example a test person who is moving in a direction from his feet towards his head, and let an acceleration act on his body in the direction of his feet, then a force of inertia  $k_1$  (Fig 3A) acts on the otolith in the direction of the crown of his head. During the same time a force  $k_2$  in the field of gravity on earth is acting permanently on the otolith. By the co operation of these forces the otolith organ will be subjected to a force  $k_3$  (Fig 3B), which is oblique in comparison with the direction of the force of gravity ( $k_2$ ). In this way the brain gets from the peripheral organ the information that a force is acting on the otolith in the direction of  $k_3$ .

Because the direction of the acting force appears to determine the apparent position of the body, the direction of  $k_3$  will indicate the apparent vertical plane. In this way the body seems to change its position and to incline backward (Fig 3C).



Not merely when the direction of the acceleration lies in the longitudinal axis of the body, but also when the test person is placed on the swing in a transverse direction, the acceleration acting from one side to the other, a similar effect is caused. The test person, besides observing to-and-fro movements, perceives the alternate rising and lowering of the right and left side. The explanation of this phenomenon may be given in exactly the same way as for the accelerations in the longitudinal axis.

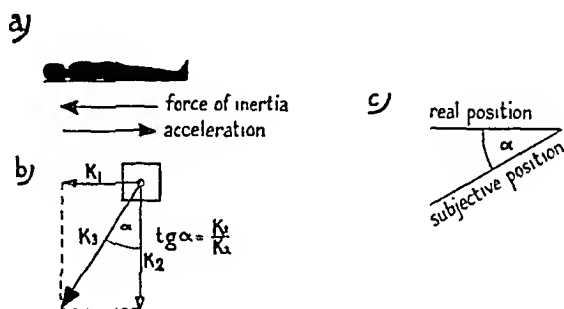


FIG. 3.

Scheme of the forces acting on an otolith organ in the cause of a combination (resultant force  $k_3$ ) of gravity ( $k_2$ ) and centrifugal force ( $k_1$ ).

- (a) acceleration and force of inertia acting on the test person.
- (b) composition of forces.
- (c) effect on the position sense.

If we now let the swing with the test person on it slowly terminate its swinging movement, this person at a certain moment will not any longer feel to and fro movements, nor changes in position of his body but a vague rhythm without a perceptible direction till finally this too will stop.

This is the moment at which the minimum of perceptibility for linear accelerations is reached. We tried to measure this minimum perceptible acceleration for different positions of the head and body of our test persons. The swing in use had a swinging length of 162 cm. and a swinging time of 2.5 seconds. With the person on his back the minimal deviation of the swing had to be from 1 to 2 cm. to give rise to a sensation. This corresponds to linear accelerations of 6 to 13 cm./sec.<sup>2</sup> at the maximum the linear acceleration acting in the direction from feet to head and *vice versa*. We examined the test persons on the swing with their heads in different positions with regard to the body. They were also examined while the acceleration was acting from one side to the other.

In the first case we obtained numerical values, having their minimum if the otolith of the utricle was acted upon perpendicularly, in the latter case if the saccular otolith was subjected to a perpendicular acceleration.

Other variations in the position of the head were also tried f.i. in the case of a longitudinally acting acceleration the change in the position of

# The Nature of the Vestibular Stimulus

the head obtained by turning the head round the same axis or by bending it towards one shoulder. These variations had no noticeable influence on the minimal perceptibility.

It would be premature to draw conclusions about the function of the otoliths from these data. As a matter of fact there is still another factor of importance involved here, namely the action of sensibility (skin—and deeper sensibility). For we noticed that quite different values for the threshold of perceiving linear accelerations were found, if a man sitting upright leans on his hands or on his elbows or doesn't lean at all on his fore limbs. We sometimes observed values varying more than 50 per cent. Besides it made a great difference what kind of underlayer we used on the swing to put our test persons on, on the wooden swing itself or on an air cushion or on a soft mattress. In the latter case the obtained threshold values were much higher (f1 on the wooden swing 6 cm/square sec, on a mattress 9 cm/square sec). It must be kept in mind that those soft underlayers may reduce the effective movements and thus the accelerations.

These data induced us to look for another method of investigation to obtain quantitative data about the function of the otoliths, because we know nothing about the extent of the influence of these tactile stimuli. On the other hand it led us to surmise that those tactile stimuli are the cause of the perception of linear displacement and that the perception of a variation in position must take place in the otolithic system. Also the fact, that a sensation of linear movement stops in the extreme position of the swing, speaks against a perceiving of this sensation by the otoliths, which perceive accelerations. In these extreme positions the acceleration is at its maximum, but the sensation zero.

Moreover the capability to sense linear movements or displacements is very poorly developed.

If in a dark room a test person lies on a riding stretcher with a soft underlayer and is moved back and forward, then after some of these movements it is impossible for him to tell the exact direction in which he is moved. On the other hand, as soon as the acting acceleration is great enough, a variation in the position of the body is observed. It is necessary to exclude as much as possible every other source of orientation (light, sound, currents of air).

Because the tactile variations interfered with our experiments in the above mentioned way we had recourse to a constant linear acceleration as is experienced on a rotating chair at constant velocity.

The sensation of leaning of the body axis is produced hereby and can be quantitatively measured, which is of the utmost importance. On the electrically moved rotating chair we gave our test-persons a definite angular velocity in different positions of the body. Then we told them to observe exactly how far they seemed to slant over. Immediately after

that they were placed in a position chair, after Grahe, improved by Quix<sup>21</sup>. The position of this chair was brought in accordance to the felt inclination, as stated by the patient. We did not ask the test persons to estimate the angle in degrees, because most people are unable to make a good estimation of the number of degrees of an angle, and in the second place, the position is not correctly estimated at an angle. Only corresponding angles may be compared with each other, in this case the inclination of the position chair (indicated on a scale) with the subjective inclination on the rotating chair.

The results of our experiments is, that the estimated inclination corresponds exactly with the angle, which the resultant of the centrifugal force and the force of gravitation makes with the latter. This angle  $\alpha$  can be calculated from the magnitude of the acceleration of gravitation and the acceleration of the centrifugal force i.e.,  $\operatorname{tg} \alpha = \frac{k'}{k_2}$  (Fig. 3B). Some experiments may serve as an example.

Test person J. lies with his head (the labyrinth) at a distance of 115 cm. from the axis of rotation. If the time of revolution  $T=10$  seconds, the faintest sensation of leaning backward is perceived. At  $T=8.2$  seconds the angle seems to be  $10^\circ$ , at  $T=6$  seconds,  $30^\circ$ , and at  $T=3.5$  seconds,  $45^\circ$ . If we check those subjective angles on our position chair, the same sensation of leaning backward is obtained by turning this chair backwards  $5^\circ$ ,  $10^\circ$  and  $20^\circ$  resp.

In a scheme the results are shown :

I	II	III	IV	V	VI	VII
Time of revolution T. sec.	Angular velocity $\omega$ rad./sec.	Centrifugal force $\omega^2 R$ rad./sec. <sup>2</sup>	Sensation of leaning backwards $\alpha$ degrees.	Same sensation at an inclination of the position chair $\alpha$ degree.	Calculated sensation  $\operatorname{tg} \alpha$	$\alpha^\circ$
8.2	0.77	65	$10^\circ$	$5^\circ$	65/981	$3.9^\circ$
6.0	1.05	127	$30^\circ$	$10^\circ$	127/981	$7.5^\circ$
3.5	1.79	368	$45^\circ$	$20^\circ$	368/981	$20.0^\circ$

Hence it is evident that the sensation of leaning backward corresponds accurately to the inclination of the resultant of centrifugal force and force of gravitation (column V and VII). It is the same in other cases of which an example is given in the next protocol, the centrifugal force acting from ear to ear.

Test person G. sits upright with his right ear towards the rotation axis, at a distance of 60 cm. from it.

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I	II	III	IV	V	VI	VII
Time of revolution T sec	Angular velocity $\omega$ rad/sec	Centrifugal force $\omega^2 R$ rad/sec <sup>2</sup>	Sensation of leaning backwards $\alpha$ degree	Same sensation at an inclination of the position chair $\alpha$ degree	Calculated sensation $\lg \alpha$	$\alpha^\circ$
10 0	0 6	22	0°	0°	22/981	1 2°
4 5	1 4	127	5°	5°	127/981	7 2°
3 0	2 1°	265	10°	15°	265/981	15 0°

We find the same striking conformity again between the calculated and the estimated values. In other positions of the body, lying face downwards, sitting upright, and so on, comparable results were obtained. But there is one position of the body, in which this conformity is not found. This is the position in which the resultant of centrifugal force and force of gravity acts in the direction of the so called blind spot of the otolithic organs (Quix). An example may illustrate this.

Test person G lies on his back with his head turned 60° further backwards, at a distance of 130 cm from the axis of rotation. The

I	II	III	IV	V	VI	VII
Time of revolution T sec	Angular velocity $\omega$ rad/sec <sup>2</sup>	Centrifugal force $\omega^2 R$ rad/sec <sup>2</sup>	Sensation of leaning backwards $\alpha$ degree	Same sensation at an inclination of the position chair $\alpha$ degree	Calculated sensation $\lg \alpha$	$\alpha^\circ$
4 5	1 4	254	0°	0°	254/981	14 5°
3 5	1 8	520	14°	5°	520/981	28 0°

angle of inclination in this case is greatly underestimated. Perhaps the explanation here has to be as follows. The skin and deeper sensibility are stimulated too by the acting linear accelerations and give an impression of a variation in position though this impression is far from being clear. On the position-chair, gravity acts on all the parts of the body and the result is a sensation from the otoliths, the skin—and deeper sensitive organs. All these stimuli act together and cause a clear sensation of the position of the body in space. On our rotating disc the action of the resultant force on the different parts of the body is different in magnitude and direction. The axis of rotation in a lying test person is through his croup. Thus the stimulus on his feet  $f_1$  is directed just in the opposite direction as on the head. At his loins only gravity is acting. When the otoliths

# HEADACHE AND SINUS DISEASE

## AN HISTORICAL SURVEY

By DEREK BROWN KELLY (Glasgow)

AMONG the common disorders, there are few more universal or distracting than headache. The sufferer, however, frequently gets little sympathy. How often is the remark heard, "Oh, it is just one of his headaches"; the possessive implying familiarity with its usual accompaniment—contempt. In spite of this, it must be realized that repeated, intractable head pains borne over a period of years, can affect the whole personality of the individual, or even his career, to say nothing of the effect on his family and friends.

Unfortunately there is still a tendency to treat the condition as a disease *per se*. The afflicted layman is encouraged in this view by innumerable advertisements, enticing him to purchase sundry proprietary "head powders", warranted to relieve his pain in not more than thirty seconds.

Some years ago there was, perhaps, an excuse for treating headaches empirically. With the present progress in our knowledge of anatomy and rhinology, however, many hitherto obscure forms of headache have been traced to their source in the nasal sinuses or ganglia.

### Historical Introduction

That the ancient medical writers were well acquainted with the complaint of headache, is shown by the following facts from the history of medicine.

Hippocrates (460 to 377 B.C.) recognized the association between the high-arched palate of nasal obstruction, discharging ears and headache, but did not attempt any classification of types or causes of head pains (Delpuech, 1898). It was not until the first century A.D. that Aretaeus of Cappadocia (A.D. 30 to 90), and later Galen (A.D. 131 to 201), advanced their theories on the subject, and produced a classification based on the Hippocratic humoral doctrine of pathology.

This maintained that the body was composed of four cardinal Humours, namely Blood, Phlegm, Yellow and Black Bile: and also four elementary qualities—Hot, Cold, Moist and Dry. The proper distribution and admixture of the former was the source of health. Any departure from this condition resulted in disease, the nature of which was

## Headache and Sinus Disease

determined by the Humour in excess, or its accumulation in any particular locality. The qualities, if in harmony produced a healthy temperament, while excess or defect of one or more gave rise to a "distemper" (Singer, 1928). Probably the best known example of this ancient doctrine is the association of headache with an excess of bile.

The terms "bilious attack" or "bilious headache" are in common use even to-day, and are accepted by the layman as a satisfactory label for many complaints. That the origin of such terms dates back to ancient times could not be shown better than by quoting Galen's own words, "How constantly do we see the head attacked with pain when yellow bile is contained in the stomach, as also the pain forthwith ceasing when the bile has been vomited."

Later Greek writers merely imitated and abstracted Galen's work, and some time elapsed before further investigations in the matter of headache were made.

During the Middle Ages there was little advancement in the science of medicine, and interest in the subject of headache seems to have been lost until the Renaissance, since when many monographs have been published and theories put forward. Interesting historical references relating to this period are given in papers on headache or "migrain" (under which heading many forms of headache were indiscriminately classified), by such writers as Whytt (1768), Liveing (1873), and Moebius (1894).

Early conceptions of nasal disorders were fascinating if erroneous. Even as late as the seventeenth century, coryza was believed to be a flux of serous fluid from the cerebral ventricles, and a cold in the head was regarded as a purging of the brain. This idea prevailed until Schneider gave his account of the anatomy of the nose and described the membrane that bears his name (Wittebergae, 1664, *De Catarrhis*).

The adjective pituitary, now denoting the membrane lining the nasal cavities, means mucous (pituita—slime or mucus) and was applied to the hypophysis by mediaeval physicians because they thought that it was the source of the yellow discharge from the nose in the later stages of a "cold" (Jamieson, 1938).

It is not surprising therefore to find in some of these old records notes of symptoms which were probably of para nasal sinus origin, but which were not recognized as such. Examples of this will be referred to later.

One of the first to appreciate the association between head pains and nasal disorders was Jacob Wepfer (quoted by Wells, 1898), who in 1728, recorded the fact that nasal obstruction caused violent headaches, disturbances of vision, and loss of memory.

In 1768, Robert Whytt wrote about periodical headaches and likened this periodicity to that of epilepsy. He suggested as a cause the gradual accumulation of morbid matter, until a stage is reached when it is dislodged by the violence of the resulting paroxysm. This theory was

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put forward without reference to the rhinological aspect or causes of headache, about which little was known at the time. Yet to the rhinologist, the above description suggests at once an infected sinus with intermittent obstruction of drainage, followed by discharge of accumulated contents and relief of pain.

Dr. Airey, in 1870, recognized that association between asthenopia and frontal headache which is now realized as being of frequent occurrence in cases of frontal sinus vacuum headache.

Among the most important works on the subject must be mentioned Liveing's treatise on "Megrim, Sick Headache, and Some Allied Disorders", published in 1873. Still regarded as a classic in this field, the book is mainly concerned with migraine and its classification into simple hemicrania, sick headache, blind headache, and headache associated with a "wider implication of the sensorium", such as the sense of touch.

Although no reference was made to the connection between headaches and the nose, Liveing mentions some significant facts indicating that several of his cases were probably of sinus origin. For instance, some of his patients had that typical frontal sinus pain which comes on in the course of the morning, reaches its maximum intensity at about 2 p.m., and then passes off, leaving the evening and night free from pain.

Changes of temperature and foul air were recognized as factors in the production of headache. That they exerted their influence *viâ* the nose was, however, not realized. Nothing was known at that time about the erectile tissue of the turbinates and how it sometimes failed to respond to temperature changes, remaining engorged, and causing obstruction to sinus ventilation. This upset of the nervous mechanism of the nose due to sudden violent changes in temperature or humidity is now recognized as being of common occurrence, especially in America where over-heated houses are combined with a low outdoor temperature in winter.

Similarly, the association of facial congestion with headache was noted by these old observers. While in some cases the headache might be due to raised blood pressure, the fact that the pain could be caused by the accompanying nasal engorgement and resulting obstruction was not envisaged.

That old-time remedy for headache, the administration of sternutatories is often mentioned. Proprietary snuffs are still sold for the treatment of nasal disorders, and find favour with some practitioners even to-day.

In his publication, Liveing records the observations of Lebert, that pain was commonly felt in the territory of the frontal nerve. Headache in this region was therefore regarded as a neuralgia, and that it could be due to inflammation in the frontal sinus was not considered.

This ignoring the part played by the sinuses in the production of head pains at this period is surprising, for suppuration in these cavities

# Headache and Sinus Disease

was described long before Liveing wrote his book. It is evident that the investigation of sinus disease originated and progressed quite apart from that of headache and it was not until about 1880 that they were linked together as cause and effect. It is interesting, therefore to return to the sixteenth century and follow the development of knowledge in sinus disorders.

## The Investigation of Sinus Disease

In searching the literature it is difficult to find many references to the discovery of the para nasal sinuses. Portal whose '*Histoire de l'Anatomie et Chirurgie*' (1770) is invaluable to the medical historian ascribes the first accurate description of these cavities to Vesalius (1543).

That the maxillary and frontal sinuses were known prior to this is undoubted. Leonardo da Vinci (1452-1519) that most versatile and remarkable man became engrossed in anatomy which he first studied to improve his art. He was the first to portray adequately and truly the skeleton, and among his drawings are some excellent figures showing a skull with antrum and frontal sinuses in section. Even the elusive sphenoidal sinus was known as far back as 1516 to Jean de Vigo, surgeon to Pope Julius II and the frontal sinuses and ethmoid were described by Berenger Carpi (1521).

The work of Vesalius is certainly important in that it gives an accurate and detailed account of the cavities and denies any communication between the sphenoidal sinus and the cranium—a view common among anatomists of the period.

Several important facts regarding the sinuses were brought to light in the sixteenth and seventeenth centuries. In 1544 Ingrassias believed that 'the sinuses of the face served in the production of the voice', and Fallopius (1561) showed that some sinuses were not present in infants while others were scarcely developed. Fallopius also described the frontal sinuses that they were two in number, varied in size and were covered with a fine membrane like the other nasal cavities.

One of the early otologists who also studied the nose was Casserius, (1600) a pupil of Fabricius. He is best known for his beautifully detailed drawings of the ossicles from the ears of man and various animals. His investigations however included the nasal sinuses and he referred to the maxillary cavity as antrum genae or antrum of the cheek.

The name of Schneider is eminent in the early annals of rhinology. Not only did he describe the mucous membrane lining the nose (Schneiderian Membrane) but he showed that a similar membrane covered the sinuses and that these cavities communicated with the nose (1641). He demonstrated the fronto nasal duct and presented the curious theory that fractures of the frontal sinus gave rise to difficulty in breathing, because 'the air inspired into the nostrils escapes from the opening in the sinus rather than penetrates to the lungs'.



Although the maxillary sinus is often referred to as the antrum of Highmore, it was evidently known and described long before that author published his famous case at the Hague in 1651.

This concerned a gentlewoman who, after the extraction of a canine tooth, thrust a silver bodkin into the empty socket and "was exceedingly frightened to find it pass, as it did, almost to her eyes. And upon further trial with a small feather stripped of its plume, was so terrified as to consult the Doctor and others about it, imagining nothing less than that it had gone to her brain." The lady was much relieved when it was explained to her that the feather had simply doubled up in the antrum.

Twenty-six years later, Antonio Molinetti published in Venice an account of a case of chronic suppuration in the antrum.

In *Anthropologia Nova*, published by Drake in 1707, William Cowper described the para-nasal sinuses. "The uppermost of these cavities is found in the os frontalis, and is taken notice of because it is so frequently seen in dividing the skull to take out the brain." He recognized the great variation in size of the two sides, and that their ducts opened into the nose under the superior turbinate (as the middle turbinate was then called).

With regard to the antrum, he writes, "to discover it fairly, divide the bone with saw or chizel near the dentes molares of the upper jaw, and you'll presently break into this large cavity, the magnitude of which will a little surprize one who has not been conversant with these matters".

He points out that the antra have small openings situated high up in the cavity, so that "peccant humours" could not escape into the nose, unless the antrum were full to the top, or the head held on one side. One of his case reports concerns a patient with "œzæna", having a discharge of stinking pus from the nose. Cure was achieved by removing the first molar on the affected side and boring a hole through the socket into the antrum. Pus was released, and medicaments daily injected *viâ* the alveolar opening until they passed out through the nose.

Another case was that of an elderly gentleman who had a fœtid discharge from his nose. He attended a dentist who was horrified, when on drawing an upper molar, found that the adjacent tooth and a piece of alveolus came away. Cowper showed that he was not to blame as the bone was rotten. The patient was relieved of his discharge, but shortly afterwards suffered from pains in the face and head and finally died in convulsions. At necropsy, the upper part of the antrum was found to be carious, and there was a sinus "through the tract of the foramen lacerum, and the opposite part of the os sphenoidales was also perforated and the dura laid bare". An abscess was present in the fore part of the hinder lobe of the brain in which an ounce of fœtid matter was found.

In 1722, Reininger published an article on œzæna and maintained that decomposition of mucus within the ethmoidal, sphenoidal and frontal

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sinuses and the antrum of Highmore, was the underlying cause of this condition. Gunz also detailed some cases in 1753 in which the odour was due to disease of the sinuses opening into the nose.

An interesting case in which an empyema of the antrum resulted in caries and loss of the upper maxilla and teeth was described by Hardisway in the *Philosophical Transactions* for 1727.

John Hunter (1835 edition) described the signs and symptoms of antral abscess as pain in the cheek and forehead, together with redness, swelling and hardness of the cheek. He advocated two methods of opening the affected cavity—by perforating the partition between the antrum and the nose, or by drawing the first or second molar, and boring through the socket. Under special circumstances "if the fore part of the bone be destroyed an opening was made inside the lip where the abscess could be felt. It was recognized that this opening tended to close more readily than the other two.

Despite the early recognition of chronic antritis, the acute stage of the disease was not described until 1751 by Runge. Three years later Bordenave (1754) recorded three cases of acute antritis following perforating wounds of the cavity. Another early writer on this subject was Frank (1745 1821) who drew attention to the involvement of the antrum in the common cold.

The nasal sinuses now began to receive mention in the text books, those of Spencer Watson (1875) and Lennox Browne (1878) being specially worthy of mention.

Peter (1878) quoted by Morell Mackenzie, records a case of acute nasal catarrh accompanied by such severe pain in the brow that the complaint was regarded as one of acute caries of the frontal bone. On the application of a poultice to the root of the nose a profuse discharge was established which instantly relieved the pain and proved the case to be one of coryza. It is interesting to note that Mackenzie makes no comment on obstructed drainage from the frontal sinus when reporting this case.

There seems indeed, a curious reluctance to admit that the signs and symptoms (including headache) of sinusitis were really due to disease in these cavities. An elaborate classification of various forms of 'catarrh' is to be found in the older text books without a mention of the sinuses which were responsible for the symptoms in many cases.

Rumbold in his book *The Hygiene and Treatment of Catarrh* (1880) observed that patients with chronic catarrh were liable to suffer from headache and melancholia and were often unable to think clearly. This is one of the first writers who recognized the association of headache with nasal disease.

In 1884 appeared Morell Mackenzie's famous *Manual of Diseases of the Throat and Nose*. In it, he referred to pain in the frontal region during an

acute catarrh as being indicative of extension to the frontal sinus of the inflammatory process.

One of the most important advances in the study of antral disease was made by Ziem. In the *Monatsschrift für Ohrenheilkunde* (1886), he gave an account of his own personal experience of antral suppuration. Until then, empyema of the antrum was not recognized unless it presented such advanced signs as profuse discharge with infra-orbital pain, swelling of the soft parts, exophthalmos, and distension of the bony walls of the cavity, with final fistula formation. Ziem's illness started in 1877 when he suffered from a unilateral, foetid nasal discharge and impaired general health. Despite various intra-nasal applications, internal medication, and two years sojourn in Egypt, the condition became worse, and the foetor so pronounced that he entertained thoughts of giving up his practice. Finally in 1883 he had his antrum opened by a surgeon who was most unwilling to operate because none of the recognized signs of empyema were present. When the cavity was explored, however, much pus came away, and eventually he was cured. (Quoted by A. Brown Kelly, 1892.)

It is interesting to note that an authority like Greville Macdonald in his text-book on *Diseases of the Nose* (1890), scarcely mentioned the frontal sinus. In fact in the chapter on "Suppuration in the Accessory Cavities of the Nose", he writes:—"Empyema of the frontal sinus is so rare apart from occlusion of the duct—in which case we have external evidence of the mischief—that we may safely exclude it from consideration." Although he recognized cases of supra-orbital pain which came on in the morning and passed off in the evening (now known to be typical of fronto-nasal duct obstruction), he considered antral empyema to be the sole cause, the frontal sinus receiving no mention.

At that period rhinologists regarded operations on the frontal sinus as being the prerogative of the general surgeon. This attitude had its counterpart in otology, few aurists at that time performing mastoidectomies, but leaving them to their colleagues with general surgical training.

The subject of sinus disease was finally put on a firm footing by Grünwald. His famous text-book *Nasal Suppuration* appeared in 1896, and was translated into several languages. The English edition was published in 1900, and is well worth reading to-day.

Valuable research devoted to nasal neurology and headache has been carried out by Sluder since 1900. This author investigated affections of the nasal ganglia and their associated head pains, besides being the first to describe the condition known as "vacuum headache".

In 1908, Yankauer described a method for diagnosing headaches of nasal origin. He showed that inhalations of steam favoured sinus drainage by shrinking the mucosa and stimulating ciliary activity. Pain which was relieved by steam inhalations was therefore probably due to

## Headache and Sinus Disease

obstructed sinus ventilation It is interesting to compare this procedure with the modern use of ephedrine in the diagnosis of nasal headache

It is impossible in a short paper to enumerate all the famous authors who have devoted time and energy to the study of sinus disease Caldwell, Luc, Ogston, Killian and Howarth will long be remembered by the operative procedures bearing their names, while Watson Williams will be associated with the careful and meticulous diagnostic methods using suction, which he devised

Following the development and establishment of operations on the sinuses, there came a period when radical surgery was too frequently employed in the treatment of nasal disease There was a tendency to operate without paying due regard to possible underlying systemic disorders such as allergy, with consequent frequent failures and occasional disasters Lately the pendulum has swung back to more conservative treatment, which received a great impetus from the work of Proetz (1931) whose displacement method of introducing drugs into the sinuses is of inestimable value in both diagnosis and therapy The sulphonamides and penicillin have also tended towards conservatism in the treatment of acute infections, thus obviating the necessity for the heroic radical surgery of only a few years ago

### Nerve Paths concerned in Nasal Headache

The close relationship between the tonus of the nasal vascular system and that of the meningeal vessels is demonstrated by Buzoianu (1937) He maintains that headache of nasal origin can be due not only to local obstruction or general toxæmia but also to stimulation of the trigeminal—sympathetic system which controls the tonus of both the nasal vascular apparatus and of the vessels of the endocranial membranes Irritation of the nasal mucosa with accompanying congestion is transmitted *via* the trigeminal tracts to the meningeal capillaries Relief of headache by application of cocaine to the nose is explained by the simultaneous vaso constriction in both nasal and dural capillaries

Cases suffering from this 'vago nasal hyper sensitivity' are recognized by the increased vascularity of the middle turbinate and structures in the middle meatus, the presence of Ewing's tender point in the frontal sinus floor, and the disappearance of headache after application of cocaine to the middle meatus

That the dural vessels are sensitive structures has been shown by Ray and Wolf (1940) and Penfield and McNaughton (1940) According to these authors, all headaches are due to disturbances transmitted through the sensory cranial nerves At intracranial operations carried out under local anæsthesia they found that pressure, distortion and other physical stimulation is painful only when applied to certain restricted areas of the brain and its coverings Among the sensitive structures are the dural

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vessels, the cerebral arteries at the base of the brain, the venous sinuses and the basal portions of the dura.

The most sensitive areas of the nasal mucosa are in the region of the ostia and the approaches thereto (Wolf, 1943). If faradic stimulation to the nasal septum produces a pain intensity graded as 1, a similar stimulation of the turbinates is graded as 4 to 6, to the naso-frontal duct as 5 to 7, and to the ostium as 6 to 9. The actual lining of the sinuses is not so sensitive, being graded as 1 to 2.

Experimentally induced pain is referred to regions of the head supplied by the second, and to a less extent the first divisions of the fifth cranial nerve. Irritation of several sites in the nose produces pain in the same region of the head and face. Thus stimulation of the septum results in pain referred to the same area as does stimulation of the ostium and the lateral wall of the antrum.

## Summary

A short historical review is given of work done in the investigation of headache, from the early theories of Galen to those of the present day. This is followed by a similar survey of sinus disease. The fact that headache could be a symptom of sinusitis was not recognized until about 1880, although suppuration in the sinuses was described as far back as 1651.

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## CLINICAL RECORD

### A BRANCHIAL CLEFT APPEARING AS A POST-TONSILLAR ABSCESS

By W. STIRK ADAMS (Birmingham)

My colleague Mr. Hugh Donovan asked me to see the patient, a gardener, aged 52, who had been in good health until three years ago, apart from symptoms of indigestion, thought to be due to a peptic ulcer.

At that time without associated symptoms or illness he noticed a foul taste in his throat, which appeared when he stooped to lift. This has continued but attracted little attention. In the past two years, he lost some two stone in weight and six months ago developed a smooth rounded swelling in the left side of his lower neck, which was regarded as a thyroid enlargement, and was associated with general symptoms of secondary thyrotoxicosis.

Examination showed him to be an alert, intelligent, well-built man. No abnormality was observed in his nasal passages, nor on transillumination of his accessory nasal sinuses. His remaining teeth were in good condition. His mouth and tongue were normal, but on pressure with the mirror on the left anterior pillar of his fauces, a large quantity of foul green sero-pus exuded from a pinhole aperture in the posterior pillar of the fauces about half an inch below the upper pole of the tonsil. His larynx was normal on inspection and his voice unchanged. Pressure on the swelling in the left side of his neck failed to produce any exudate from the aperture.

X-ray examination of his neck showed no evidence of foreign body, though swelling of the tissues between his trachea and his cervical spine was well defined, and this space appeared twice the usual width.

The most likely diagnosis appeared to be a persistent discharge from a chronic peritonsillar abscess.

At operation on *November 26th, 1946*, a blunt bistoury was inserted into the pinhole in the pillar dividing it for one inch downwards. The tissues were not indurated. His left tonsil was then removed by dissection without opening the abscess cavity which was then seen to occupy the posterior half of the tonsil bed and appeared as a cushion like a "half-filled rubber water bottle" without induration, in size about 1 in. by 1½ in., in this region. It was grasped with Luc's forceps and incised. Its interior wall was smooth, without granulations or inflammatory reaction. The capsule was readily detached from the surrounding tissue and was found to be the upper expanded end of a tube, through which the end of a No. 4 rubber catheter was passed to a level about half an inch above the cornu of the hyoid. The tube lay free on the superior constrictor muscle.

These findings suggested that the condition was the upper end of a branchial cleft, which had been regarded as a possibility prior to operation. The tube was divided at the lowest part of the open tonsillar bed, after a ligature had

## Clinical Record

been placed around it. The opposite tonsil and the adenoid was then dealt with.

His post-operative recovery was uneventful, and the swelling in the left thyroid region receded in size so rapidly that a fortnight after operation, it was scarcely palpable. In view of this the operation to expose the descending part of the track from the thyroid region downwards, was thought to be unnecessary, and the patient returned home well.

Microscopy of the capsule revealed an epithelial lining of the cyst, consistent with it being a branchial cyst.

### Commentary

This case is placed on record because it appears to answer the question where the opening of the upper end of this branchial cleft can be expected. Text-books and clinical experience describe the track of a third and fourth branchial cleft as passing between the internal and external carotid artery, and ending on the deep aspect of the tonsil. Unfortunately the decision not to proceed with the exposure of the track in the neck raises an element of doubt whether the cyst removed was in fact the expanded upper end of the branchial cleft, but no other explanation seems possible. If it is accepted as a branchial cleft, its opening in the posterior pillar of the fauces and its complete freedom of attachment to any part of the tonsil capsule, suggests that a hypothesis previously favoured by the reporter, that the palatine tonsil is the lymphatic guard of the primitive opening of this branchial cleft must remain doubtful.



# SOCIETIES' PROCEEDINGS

## ROYAL SOCIETY OF MEDICINE—SECTION OF LARYNGOLOGY WITH SECTION OF OTOTOLOGY

COMBINED SUMMER MEETING HELD IN LONDON

June 14th, 1946

### LARYNGOLOGICAL SESSION

*Chairman*—G. EWART MARTIN, F.R.C.S.ED.  
(President of the Section of Laryngology)

#### **The Application of Electromyography to Affections of the Facial and the Intrinsic Laryngeal Muscles**

By B. FEINSTEIN

ELECTROMYOGRAPHY is a delicate gauge of the damage to the lower motor neuron and it has proved of value for the accurate assessment of peripheral nerve injuries and the early stages of diseases affecting the lower motor neuron. Among other pathological conditions, it has been an aid in the diagnosis and prognosis of facial and laryngeal muscle affections (Weddell, Feinstein and Pattle, 1944). Muscles which perform finely graded movements such as those of the face and larynx have motor units composed of fewer muscle fibres than those muscles, such as of the limb, which are only capable of much coarser movements. The action potentials are similarly less in duration (2 to 5 milliseconds) and smaller in amplitude (50 to 500 microvolts).

*Facial paralysis.* Electromyographic examinations have been carried out in more than 150 cases of facial paralysis due to affection of the lower motor neuron. The cause of the paralysis, in the majority of the cases, can be divided into two clearly defined groups.

In the first group, the paralysis is due to trauma, either direct or indirect, and in the second, the paralysis is due to pressure by inflammatory oedema on the nerve trunk in its course through the temporal bone, resulting in an ischaemic block. In this group can be included the paralysis found in such conditions as Bell's palsy, herpes zoster and otitis media.

It has been found that the facial paralysis following a head injury in the majority of cases is apparently due to an ischaemic block rather than to an interruption of the axons. This would account for the observations of Turner (1944) that the prognosis in facial paralysis of this type is good. Twelve cases of traumatic facial paralysis were examined electromyographically. In four of these, there was no evidence of denervation and each made a complete recovery, but, in each of the other cases, there was a varying number of axons interrupted. Recovery occurred but associated movements were present in every instance.

# Royal Society of Medicine

The findings suggest that in cases of complete axonal interruption following direct trauma, where there is no gross displacement of the nerve at least six months should elapse before operative procedures such as exploration and grafting are to be considered. In such cases electromyographic examinations are valuable in detecting minimal degrees of re-innervation before the return of functional recovery. In those cases where the skiagrams demonstrate a fracture and displacement of the mastoid tip earlier operation is justified. In cases of closed head injuries the prognosis regarding the recovery of facial paralysis is so good that early decompression of the facial nerve is not warranted.

It is not possible by means of electromyographic examination to differentiate between an axonal interruption and a reversible ischemic block for about twelve to fourteen days following the nerve injury, as it is not until this time that fibrillation commences.

The demonstration of even a single repetitive motor unit action potential is of great prognostic significance in a case in which clinically the paralysis is complete, as it indicates that a few nerve fibres have escaped damage and therefore suggests that the lesion is in continuity.

In the cases of the infective group i.e. Bell's palsy herpes zoster and otitis media electromyographic examinations confirm the clinical observations, but in addition offer a more detailed analysis of the nature of the paralysis. This is particularly valuable in assessing the prognosis. In mild cases of facial paresis, there was a reduction of motor unit activity in response to a maximum voluntary effort to move the muscles but no other abnormalities. Recovery both clinically and as shown by means of electromyographic recordings was complete within a few weeks. In instances where the facial weakness was more marked and associated with a considerable degree of lower motor neuron denervation, recovery resulted in marked associated movements. This is accounted for by the fact that many of the regenerating axons do not follow their original pathways and dichotomization of the axon is frequent. The work of Howe, Tower and Duel (1937) has placed the phenomenon of associated movement following re-innervation on an anatomical basis and the ultimate prognosis regarding the dissociated movement of the facial muscles is poor in view of this abnormal pattern of innervation. It may be possible however in some instances to improve the degree of recovery. Two cases of facial paralysis in which there was complete axonal interruption were followed through to functional recovery and their treatment carefully controlled. They were started on a daily session of 'galvanism' and were also shown how to massage their faces, which they did a number of times daily. In addition the angle of the mouth was kept elevated by means of a facial hook. Electromyographic recordings were made at weekly intervals and soon after the appearance of the first motor unit action potentials slight movement was observed on attempted voluntary contraction. The galvanism was then stopped and the patient began to practise individual facial movements in front of a mirror every day. The mode of regeneration and basis of associated movements were explained to the patients. In both instances the patients were co-operative and in both cases associated movements were less than was usually seen.

Ballance and Duel (1932) have advocated that the facial nerve should be decompressed immediately a facial paralysis is seen in order to prevent axonal

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interruption, but, in view of the work of Denny-Brown and Brenner (1944a and b), it does not seem likely that many operations could be carried out in time to be effective. Furthermore, it is doubtful, from the anatomical point of view, whether exposure of the facial nerve from the lateral semicircular canal to the stylomastoid foramen and incising its sheath, is an adequate decompression. Kettel (1943) analysed a large number of cases of facial paralysis, associated with otitis media or mastoid infection, but came to no definite conclusion as to the optimum time for operation. He was, however, of the opinion that in cases of immediate complete facial paralysis following mastoidectomy or labyrinthectomy, the facial nerve should be explored within seventy-two hours. In these cases, the operation of decompression seems to be of theoretical rather than practical value.

In one case of Bell's palsy, the paralysis persisted for six weeks but at no time was fibrillation, indicative of a lower motor neuron denervation, detected and recovery was complete and movements were normal. This is of interest for it suggests that the condition of a reversible ischaemic block may persist for very long periods.

There were three cases of very long-standing paralysis in which there was marked contracture. The contracture was confirmed as being due to fibrous metaplasia, for there were numerous areas of electrical "silence" in the facial muscles when electromyographic examinations were made. These patients had received no physiotherapy.

*The intrinsic laryngeal musculature.* In order to record the action potentials from the intrinsic muscles of the larynx, it was necessary to use a concentric needle electrode of sufficient length so that all manipulations could be carried out through a laryngoscope.

The intrinsic muscles of the larynx have been investigated in a number of cases. The motor unit action potentials resemble those obtained from the facial musculature. The needle was first inserted into the lateral crico-arytenoid muscles and the subject requested to abduct the cords by taking a deep breath. There was continuous motor activity as long as the cords were abducted. When the cords were adducted, the motor unit activity decreased but did not die away completely. Thus the abductor muscles, even when the cords are adducted, maintain a certain amount of "tone".

Electromyographic examination has been found to be of value in cases of "idiopathic laryngeal palsy". In a few of these cases, normal motor unit activity was obtained from the muscles which were thought to be affected, and the immobility of the cords was shown to be due to ankylosis of the arytenoid cartilage. A certain degree of recovery in these cases is possible by re-education. Vocal cord paralysis as a result of denervation of the intrinsic laryngeal muscles was diagnosed by the presence of fibrillation action potentials. In these cases, recovery was not so good although it was possible at times to pick up polyphasic motor unit action potentials indicative of re-innervation.

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R. G. MACBETH described electromyography of the laryngeal muscles, first giving the technique and then proceeding to some illustrative cases. The patient was premedicated and prepared with surface anaesthesia as for any direct laryngoscopy, and the larynx was examined by the ordinary routine. Any diagnostic laryngoscope might be employed. Usually the crico-arytenoideus lateralis muscle was initially explored, on the unaffected side first and then on the affected side. Then the posticus muscles were similarly explored. The lateralis muscle was reached by inserting the bipolar electrode through the aryepiglottic fold lateral to the cord. The posticus muscle was reached by passing the beak of the laryngoscope behind the aritenoids to each side of the mid-line in turn and inserting the electrode 1 to 2 cm. below the level towards the back of the cricoid cartilage. The patient was instructed to phonate or breathe deeply as required. By this technique doubtful cases of paralysis, crico-arytenoid fixation, and hysterical aphonia might be diagnosed with reasonable certainty. No untoward effects of the examination, except slight soreness, had been noted to date.

Mr Macbeth then mentioned three illustrative cases.

(1) A lieutenant in the U.S. Army Air Corps was hit in the neck by a piece of flak. This had entered anteriorly on the right side and come to rest in the posterior muscles. He had become hoarse immediately after being struck, and remained so. Laryngoscopy showed the right cord immobile in the cadaveric position. Electromyography one month later revealed complete axonal interruption of the recurrent nerve on that side.

(2) A sergeant in the same Corps was hit in the neck near the larynx on the right side by flak. There was a history of considerable swelling in the region of the thyroid cartilage, which had subsided, and of hoarseness, which had persisted. Laryngoscopy two months later showed the right cord fixed in abduction and some thickening of the aryteno-epiglottic fold. Electromyography showed intact innervation on the affected side. Crico-arytenoid ankylosis, already suspected clinically, was thus confirmed.

(3) A Guardsman was undergoing preliminary training when he fell upon a tree-trunk and badly bruised the right side of his neck. There was considerable swelling, which subsided, and hoarseness, which persisted for six months. He had been discharged from the Army with a diagnosis of recurrent laryngeal nerve paralysis, after having been examined by a number of otolaryngologists. When seen in civilian life the right cord was in the cadaveric position and nothing else was to be made out clinically. X-rays of the laryngeal cartilage showed no fracture. Electromyography of the laryngeal musculature showed full motor activity on the affected side. His discharge diagnosis was thus disproved, and it became clear that he had a fixation of the cricoid-arytenoid joint.

## A New Œsophagoscope

MARTIN HENRY said that the distally illuminated œsophagoscope of the tubular type gave admirable illumination at the position where it was most

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needed, but it was difficult to manipulate, and being necessarily of the tubular pattern the field of view was restricted. The disadvantage of the proximally illuminated type of instrument was that, while giving an admirable open field at the end of the scope, it had diminished illumination.

He had designed an œsophagoscope which gave an open field of view at the distal end, was easy to manipulate, and afforded adequate illumination. A definite improvement in the illumination of proximally illuminated instruments could be obtained by aligning the lamps, so that they bore directly on the distal end of the instrument. Existing instruments carrying their lights in long tubes were focused on the walls of the main tube, the illumination finally reaching the tip of the œsophagoscope by means of cross reflection, so that a proportion of the illuminating power of each bulb was lost. In his instrument the lamp-carrying tubes, instead of being some inches long, were only just long enough to prevent reflection from the bulb reaching the surgeon's eye. In this instrument the lamp-carrying tubes were inside the œsophagoscope. If the instrument was examined without the lamp-carrying saddle in it would be noted that whether the observer looked through the lumen of the main tube or down either of the empty lamp-carrying tubes a complete view of the field afforded by the tip of the instrument was obtained.

He had had these instruments made in very much larger sizes than usual, first because the larger the instrument the easier it was to find the way into the œsophagoscope, and secondly because the chief limitation to the size of the œsophagoscope was not the size of the œsophagus, which was enormously dilatable, but the antero-posterior space between the upper and lower teeth. One of these models was built for edentulous adults and in spite of its large size would pass freely down the œsophagus of any edentulous adult without inflicting any trauma.

These œsophagoscopes were made in the following sizes: 30 cm. for children; 40 and 30 cm., medium adult; 40 and 30 cm., large adult; 40 and 30 cm., edentulous adult.

June 15th, 1946

### CLINICAL MEETING AT TORBAY HOSPITAL

Chairman—G. EWART MARTIN, F.S.C.S.Ed.

(President of the Section of Laryngology)

#### *X-ray Films of Radium Needles in situ following Fenestration Operation.*

The operation was performed by MR. NEGUS and MR. BRADBEER in December, 1941. Dosage 8,640 mgr. hrs. Patient free from recurrence, but in September, 1945, had an attack of perichondritis and coughed up a piece of cartilage.

V. E. NEGUS said that this was an elderly man who was considered unfit for an excision operation, with a growth which extended along one cord. The moral of the case was that there was a use for the application of radium to the larynx. It seemed to him that radium was more logical than radon. Deep X-ray treatment for the larynx he thought to have disadvantages, and it was upsetting to the patient. Teleradium with a 5 gramme unit was less so, but many patients complained during the treatment and some wanted to stop it.

# Royal Society of Medicine

It took four to five weeks, whereas the application of radium needles might be over in about seven days. The previous week he had seen a patient who had had the larynx irradiated by teluradium four years ago and had had a mild perichondritis ever since. This did not seem to occur so much with needles. The present patient had been perfectly well for some years, and then this attack of perichondritis developed four years after the operation. He could not think that Mr. Harmer's recommendation to use radium needles should be put aside without due thought; there seemed to be certain conditions in which it might be a very suitable form of treatment.

THE CHAIRMAN said that he had had two cases in which the condition had apparently cleared up, and after eighteen months or two years perichondritis had developed on the other side.

V. E. NEGUS said that the dosage might have been a little higher than necessary. Harmer now recommended four vertical and two horizontal needles—a total of 10 mgr. for seven days. He thought the way to avoid perichondritis developing on the opposite side was to ensure that the foremost needle was not too near to the cut edge of the thyroid ala.

J. C. HOGG said that he had assisted Mr. Douglas Harmer in a large number of these cases and could vouch that they did extremely well on the average. The actual screenage was extremely important, if the development of perichondritis immediately or subsequently was to be avoided. Mr. Harmer had originally employed 0.5 mm. platinum filter, but he went rapidly to 0.6 and now never employed anything less than 0.8, and with this he had had far less trouble with post-operative sepsis and subsequent perichondritis. In fact, he had not had perichondritis due to this operation for some time now.

On the question of a horizontal or vertical palisade, a team of physicists at Mount Vernon produced a paper on the physics of the arrangement, showing just where the maximum dosage was received. He joined issue slightly with Mr. Negus as to the indications for this procedure. By and large, those cases which had a growth extending on to the arytenoid were not so favourable from the physical aspect. The intensity was not retained in that area owing to the depth of the growth from the needle, and therefore those cases had not relatively as good a prognosis as they would have with laryngectomy. On the other hand, it could be said quite definitely that cases which were limited to the middle third of the cord or the anterior commissure would obtain cure or relief as readily as the cases which had the cord removed, and with much better voices afterwards. There was no doubt that of the two elements, radon or radium, radium needles were far better. Mr. Harmer was unable for a short period at the beginning of the war to obtain radium needles and had to use radon for a time. In his opinion the radium needles were far better.

E. D. D. DAVIS said that one of the disadvantages of the use of radium implantation was that there was considerable suppuration and a puckered scar was left in the neck. For his own part, if he could not have a complete excision and if he had to have radium or deep X-rays, he would prefer X-ray therapy.

THE CHAIRMAN said that in Edinburgh they had a cancer research department of which the radiologist was in charge. In every case from the pathology department which was diagnosed as tumour, a report was sent direct to the cancer research department. If the growth was in the centre of the cord,

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extending slightly below, it was considered very much better to use radium, but if further back this was thought to be useless. Teleradium had been almost given up in favour of deep X-rays of heavy voltage, nearly up to one million. The fenestration operation gave a better voice result than the treatment of the cord by deep X-rays. When there was recurrence after the use of deep X-rays nothing could be done apart from attempting laryngofissure, but if radium needles had been used, deep X-rays could be used later on from the opposite side with suitable screening.

V. E. NEGUS said that he would not like to give the impression that he recommended abandonment of operation. For a limited growth of a low grade clear of the vocal process of the arytenoid, laryngofissure was a suitable treatment. It was a certain operation; the voice was not quite as good as after irradiation, but there were none of the unpleasant after-effects that might be associated with any form of irradiation, and the voice was serviceable for all purposes. It would be a pity if the operation were abandoned. It was for the case where laryngectomy would ordinarily be required, that radium must be considered. He did not know whether Mr. Hogg was recommending that laryngofissure should be abandoned; many people felt that the case most suitable for irradiation was the case also most suitable for operation. If one could expect 75 or 80 per cent. of success with the laryngofissure operation, that should be a recommendation.

J. C. HOGG said that the question whether laryngofissure should be retained or abandoned was entirely one for the individual surgeon. Those accustomed to use radium could produce results equally good from the mortality point of view as those accustomed to do laryngofissure; but in the hands of the occasional user of radium the results were not so good.

### *Xanthoma of Upper Jaw*

Man, aged 39, ex-R.A.F. Admitted March, 1946, with proptosis and failure of vision in right eye. X-rays showed opacity of right antrum. Exploration revealed a large encapsulated tumour expanding the antrum; this was removed. Severe hæmorrhage necessitated packing. There was still a fistula on discharge from hospital on May 1st. Vision improved from 6/60 to 6/9, with disappearance of central scotoma and improvement of field. The fistula has now healed and the nose is normal.

W. H. BRADBEER said that this was one of those cases which looked formidable at first but ended happily. Xanthomata were not uncommon in the skull, especially in the petrous bone. Sometimes they were single, but there were multiple cases occurring especially in the long bones. In some cases there was also proptosis and disturbance of pituitary function, and the condition was known as the Hand-Schüller-Christian syndrome. One interesting point was that this condition tended to occur in jaundiced patients. This patient was suffering on admission from a sharp attack of benign tertian malaria, with a marked anæmia (Hb 60 per cent.) so that it was possible he might have some hæmolytic jaundice in connection with his xanthoma.

*Blastomycosis of Nasal Mucosa* (shown by Dr. ALLEN at Mr. BRADBEER'S request).

Woman, aged 63. Treated since April, 1945, for extensive blastomycotic

lesions of skin Great improvement following X-rays, potassium iodide and gold treatment Nose shows small perforation of septum and granular condition of inferior turbinates from which the *Blastomyces dermatitidis* has, on one occasion, been identified

H W ALLEN (Exeter) said that this was one of the first cases of the American type described in this country The patient was first seen by him in April, 1945, complaining of skin trouble affecting the cheeks and nose for a year There were a number of minor complaints—chilblains, etc Two or three years previously she had laryngitis The present skin trouble started as a rash under the skin, later forming a crust when the crust came off, a red patch was exposed and pus could be expressed Microscopic examination of the pus showed typical blastomycetic mycelium and yeast-like double-contoured cells, which he thought he confirmed by culture [He showed two cultures which had been obtained from the case shown and from another case of ulcerative blastomycosis, the latter had been reported on as a blastomyces, but this appeared to him to be questionable, the former was considered to show a fairly typical colony of *Blastomyces dermatitidis* with abruptly rising edge and eccentric areola] There was no question of residence abroad in this case, and the only suggestion that this could be American blastomycosis came from the fact that American negro troops had been in the neighbourhood where she had been staying X ray treatment of the face was advised, to which the skin responded readily She responded to iodide and salicylates as well In July, 1945, the pulse rate was 100 a minute at which it still remained, she lost her slight pyrexia for a time, but relapses occur The nasal condition was noted in October, 1945, he thought there was a perforation of the septum Gold treatment seemed to have improved her, or at any rate to have done her no harm An X ray photograph of the chest was also taken, but no complete evidence that the disease was spreading to involve the lungs had been obtained The X-ray shows infiltration at left base as a light diffuse shadow Mr Bradbeer confirmed that cultures from nasal mucosa and skin were positive

THE CHAIRMAN said that he had seen three cases of blastomycosis of the chest None of the physicians had heard of it, and in most of the recent books there was no mention of it If he had seen this case without the history he would have said it was typical of lupus

E D D DAVIS said that he thought this was a case of lupus There was a lacrimal sac infection, and there were scars on the tip of the nose and of a gland excision in the neck

## *Non-malignant Stricture of Œsophagus*

Woman aged 29 History of difficulty in swallowing for about three months. Was said to have swallowed some potassium permanganate crystals X-ray showed obstruction in upper third of œsophagus Wassermann reaction negative Œsophagoscopy revealed a stricture which has been dilated three times with only temporary improvement

W H BRADBEER showed this case for information

V E NEGUS said that in the treatment of this case a large œsophagoscope was required It was important to see what the surface was like, whether the epithelium were denuded or not Generally speaking, the result ought to be



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good with simple dilatation. There was a great difference in the way it was done. If bougies were put through a tight stricture one was likely to strip the epithelium. He used the dilating bag which slipped down a guide, and this bag when blown up would dilate to the size of four fingers. Possibly the stricture would have to be dilated every six months. In a small boy aged 1½ years, in whom the X-rays were identical with those in the case now shown, and in whom there was an under-development of the œsophagus at this point, as there was in congenital shortening, with lack of proper covering by epithelium, he had tried to improve matters by applying a skin graft, by making a little bag in a dumb-bell manner which could be blown up with a graft on it. He would have said that in a case like the one shown there was no radical treatment possible. Anastomosis would prove to be unsatisfactory.

IAN ROBIN asked how tight was the stricture.

W. H. BRADBEER said that it dilated very easily. He had dilated three times in two months and the patient only improved for a short period.

IAN ROBIN suggested that the patient might be instructed to pass a mercury bougie herself daily. He had a similar case which he had to dilate with olive bougies on a string, and then the patient was quite comfortable passing the mercury one, at first before every meal and now once a week.

A. J. WRIGHT said that a good deal depended on the stage of the stricture. If there was recent injury of the œsophagus, provided the patient could be kept in a reasonable state of nutrition, the wise thing would be to leave it alone for six months or so. Interference in the acute stage of any œsophageal lesion tended to make matters worse rather than better. But it was rather difficult to say whether this was recent or not.

THE CHAIRMAN said that he hoped to show the results in four cases seen in children who had traumatic strictures following the swallowing of sulphuric acid or something of that kind. The œsophagoscope had been used and a dilator passed through to determine the consistency of the stricture and then a gastrostomy had been done. The curious thing was that all these children who were able to carry on at school with a gastrostomy tube would have an ounce of milk given by the gastrostomy tube in the morning and this set up a reverse peristalsis which actually dilated the stricture, so that they could be given a soft meal, almost an ordinary meal, by the mouth in the afternoon. Two of these cases were now fit radiologically and accepted an ordinary sized œsophagoscope. The other two had so much improved that he thought the gastrostomy tube would be removed quite soon.

## ABSTRACTS

### NOSE

*Packing for Nasal Bleeding* KARL MUSSEY HOUSTR, M D (Philadelphia)  
*Jour A M A*, September 21st, 1946, CLXXII, 144

In spontaneous nasal hæmorrhage or in severe bleeding following nasal surgery the writer uses half inch oxidized cellulose gauze packing. It is inserted in sufficient quantity and with sufficient pressure to control the bleeding but removal is unnecessary. In about 48 hours it becomes a jelly-like mass and comes away without instrumentation. It does not become foul smelling like ordinary gauze packing. It may be used with a post nasal pack.

ANGUS A CAMPBELL

### EAR

*Penicillin in Infections involving the Central Nervous System and Skull*  
H C NAFFZIGER, M D HELEN WARNER A B WALTER E STERN M D,  
ROBERTA TENISON M D and H J MCCORMACK M D (San Francisco)  
*Jour A M A* August 10th 1946 CLXXI 1183

During the past two years the writers have treated with penicillin 37 patients who had infections involving the skull and central nervous system. Of a group of twelve patients with pneumococcal meningitis nine recovered. The cerebrospinal fluid cultures of all patients who survived were sterile after 24 to 72 hours of combined systemic and intrathecal treatment with penicillin. Two patients with streptococcal and one with staphylococcal meningitis recovered although one of the former was left with a severe mental impairment.

In the treatment of eight patients with osteomyelitis of the frontal bone the immediate results were good but recurrences took place in all cases unless radical surgical excision of the infected areas was carried out as well.

In early acute infections originating in the middle ear the results of penicillin therapy alone were good but well established acute or chronic infections of mastoid origin usually require surgical procedures in addition.

ANGUS A CAMPBELL

*The Use of Residual Hearing* A C FURSTENBERG M D Ann Arbor  
(Michigan) *Jour A M A* September 21st 1946 CLXXII 138

None of the present plans for the prevention of deafness is ideal. The point where prevention terminates and therapeutic procedures begin must be clearly discerned. In children a mass of adenoids encroaching on the eustachian tubes is an important ætiological factor. After the removal of adenoids, radiant energy may be useful in the destruction of lymphoid tissue responsible for the occlusion of the eustachian tubes.

Otosclerosis is a pathological and clinical entity which has successfully

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good with simple dilatation. There was a great difference in the way it was done. If bougies were put through a tight stricture one was likely to strip the epithelium. He used the dilating bag which slipped down a guide, and this bag when blown up would dilate to the size of four fingers. Possibly the stricture would have to be dilated every six months. In a small boy aged  $1\frac{1}{2}$  years, in whom the X-rays were identical with those in the case now shown, and in whom there was an under-development of the œsophagus at this point, as *there was in congenital shortening, with lack of proper covering by epithelium*, he had tried to improve matters by applying a skin graft, by making a little bag in a dumb-bell manner which could be blown up with a graft on it. He would have said that in a case like the one shown there was no radical treatment possible. Anastomosis would prove to be unsatisfactory.

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intravenously. Oral administration is useless in systemic infections and if the drug be nebulized in bronchial infection very little streptomycin is absorbed through the lungs

There were a hundred cases of *Hæmophilus influenzae* meningitis reported of these 66 were cured clinically and bacteriologically while under treatment, thirteen improved under treatment and finally recovered, one improved but relapsed, three showed no effect and seventeen died. Late treatment after other forms of therapy have failed is most unfavourable

Streptomycin is extremely effective in tularæmia, but has little or no effect on typhoid

Results are striking in infections of the middle ear caused by Gram negative organisms. It was used prophylactically with satisfactory results in three cases

The article is lengthy has eight tables and bibliography

ANGUS A CAMPBELL

*Development of Streptomycin Resistance during Treatment* MAXWELL FINLAND, M D, RODERICK MURRAY, M D H WILLIAM HARRIS, M D, LAWRENCE KILHAM, M D and MANSON MEADS M D (with the technical assistance of CLARE WILCOX Boston) *Jour A M A* September 7th, 1946, cxxxii, 16

The early laboratory and clinical experiences with streptomycin have already indicated that acquired resistance may be of considerably greater importance with this agent than with penicillin or the sulfonamides

Of twelve cases with various Gram-negative bacilli treated with streptomycin, eight failed to show any beneficial effects. The failure in each instance was associated with a rapid development of extreme resistance to streptomycin

ANGUS A CAMPBELL

*Streptomycin Its Clinical Uses and Limitations* DONALD R NICHOLS, M D and WALLACE E HERRELL M D (Rochester, Minn) *Jour A M A*, September 28th, 1946, cxxxii, 200

Streptomycin has been found to be active in vitro to a variety of gram-negative and Gram-positive bacteria. Various strains of the same bacterial species may differ widely in their sensitivity to streptomycin

Oral administration is of little or no value in systemic disease

Intramuscular administration is the method of choice but the drug may be given intravenously, subcutaneously and intrathecally. Streptomycin introduced into the tracheo-bronchial tree by nebulization is not absorbed into the blood stream in significant amounts. It is of definite value in the preparation for pulmonary resection in cases of bronchiectasis. Further investigation into the treatment of non surgical bronchiectasis appears to be indicated. Streptomycin does not exert a rapidly curative effect on clinical tuberculosis. *Hæmophilus influenzae* and tularæmia respond satisfactorily to treatment with this drug

## Abstracts

Temporary symptomatic improvement occurs in the treatment of ozæna. Best results are obtained when the organism is *Proteus vulgaris* or *Aerobacter aerogenes*.

Meningitis due to *Hæmophilus influenzae* responds satisfactorily.

Streptomycin is of doubtful value in osteomyelitis.

The elimination of the organisms sensitive to streptomycin frequently may favour the growth of bacteria which are sensitive to penicillin. There is no contra-indication to the simultaneous use of both streptomycin and penicillin.

ANGUS A. CAMPBELL.

# The Journal of Laryngology and Otology

(Founded in 1887 by MORELL MACKENZIE and NORRIS WOLFENDEN)

November 1946

## LABYRINTHINE FENESTRATION— THE PRESENT POSITION

By C A HUTCHINSON (Salisbury)

THERE have been many references in both the medical and the lay press to the operative treatment of otosclerosis, while unfortunately certain periodicals have published the most extraordinary and wild claims on its behalf. Otologists in this and many other countries are taking an ever increasing interest in the subject and several of them are beginning, or are about to begin, to try their hand at it. therein lies the danger, and the time is, therefore, surely ripe for a dispassionate survey of the whole field and an attempt to present the naked facts stripped of all embroidery, to point out the dangers and to describe in detail a technique whereby such dangers may be reduced to a minimum.

It is not proposed in this article to discuss either the ætiology or the pathology of otosclerosis—these have already been dealt with *ad nauseum* elsewhere. Since, however, the differential diagnosis is of such importance and has for some reason received but scant attention, it may serve a useful purpose to give a brief summary of it —

### Differential Diagnosis

#### I Otosclerosis

(a) *Symptoms* The patient with a family history of resistant progressive deafness occurring relatively early in life often shows *tinnitus* as the first symptom. Such *tinnitus* is as a rule "central", is at first intermittent but may become continuous and very intense, and the rapidity with which the condition progresses varies with the intensity of the *tinnitus*.

*Progressive Deafness* for all tones develops, but often the first symptom of the onset of otosclerosis is the inability to hear low general conversation

At first unilateral, the deafness is very little influenced by climatic changes and is worse after fatigue. When well developed, deafness for high tones is marked.

*Vertigo* is occasionally found.

*Paracusis* is often marked but is "false" in character.

(b) *Signs*. The external auditory meatus tends to be glazed and dry. The tympanic membrane may show no abnormality; but on the other hand the "flamingo red" tinge of the promontory (due to congestion) may show through, and when seen is pathognomonic. The eustachian tube is often widely patent.

*Note*. Eustachian obstruction or the presence of chronic suppurative otitis media do not negative a diagnosis of otosclerosis.

(c) *Tests*. Show an advanced degree of conduction deafness, i.e., Schwabach's test may show bone conduction to be normal or increased but Rinne's test is negative.

(d) *Audiograms*. Are of less use in diagnosis than was hoped, since audiograms taken by different operators using various techniques, regardless of the effects of differing noise levels, show such wide variations that their accuracy cannot be accepted except as a very rough guide. They are of value, however, in assessing the improvement after operation—provided they are taken both before and after operation by the same technician under identical conditions with the same apparatus and technique in a sound-proof room.

## 2. *Membranous Periotic Deafness*

(a) *Tinnitus* is referred as a rule to the affected ear.

(b) *Progressive deafness* of one of three types:—

- i. Considerable high tone loss and a negative Rinne for high tones (mucosa in region of foramen ovale affected).
- ii. Considerable low tone loss while high tones are heard moderately well (mucosa in region of foramen rotundum affected).
- iii. Good or at least fair auditory acuity for middle tones and progressive loss of hearing towards either end of the register (mucosa in region of both foramina affected).

## 3. *Presbycusis*

High tone loss is the prominent feature.

## 4. *Measles and Scarlatinal Deafness*

The most common causes of nerve type deafness in children—marked high tone loss.

## 5. *Mumps Deafness*

Rare but often very severe. As a rule unilateral and is very often associated with evidence of vestibular involvement.

## 6. *Luetic Deafness*

Nerve type deafness with high tone loss. It is very common and of all varieties of nerve type deafness responds best to treatment.

Lastly in the following three conditions we get deafness very similar to periotic deafness, but, while it may be of extreme degree, it can be restored quite suddenly almost or quite to normal.

# Labyrinthine Fenestration

## 7. *Auditory Fatigue*

Temporary recovery occurs after rest

## 8. *Cochlear Ischæmia*

The inhalation of amyl nitrite or listening to a loud buzzing (Bárány's Box), both of which congest the cochlear vessels, will temporarily restore the hearing

## 9. *Over-stretched Tensor Tympani*

Manifested by so called "curtain deafness", where there is deafness for conversation coming on in waves, while there is good hearing for simple tones. Temporary recovery of hearing can be secured by the use of artificial wax in the external auditory meatus. (A good formula for which is one dram each of spermaceti and cera flava to the fl oz of lanoline.)

## Objects of Surgical Treatment

Now since the essential feature of otosclerosis is the inability (thanks to ankylosis of the stapes footplate in the foramen ovale) of sound waves to set up vibrations in the labyrinthine fluids and so stimulate the cochlear nerve endings in Corti's organ, operative treatment aims at by-passing the obstructed foramen and so effecting a new route of access for the sound waves. It is obvious, however, that for such operative procedure to have a chance of success there must be good hearing by bone conduction, indicating an intact organ of Corti and a functionable hearing centre.

## Development of the Technique

The chapter opens with Kessell's efforts in 1876, but though Kessell, Passow, Barany, Jenkins and others tried various sites and techniques for labyrinthine fenestration they had nothing save failures to report until, as recently as 1920, Holmgren of Stockholm met with some success with his fenestration of the external semicircular canal.

In 1921 Sourdille of Nantes was able to report some success with fenestration of the external semicircular canal and the employment of a tympanomeatal flap to cover the fenestration. He too, however, frankly admitted many failures. In 1932 he was at last able to report a fair proportion of successes out of one hundred and fifty operated cases.

In 1935 Holmgren reported further successes. Meanwhile he had been trying out many different approaches and employing a variety of materials to cover the fenestration—including Thiersch grafts, stent, fat, gold leaf and paraffin. Both Holmgren and Sourdille favoured a three stage, and later a two stage, operation with a postero superior approach.

In 1938 Lempert of New York published a one stage transmeatal technique of his own claiming considerable success for it.

The writer's interest in the procedure dates from 1932 and was inspired by Sourdille's results. After trying out various sites for fenestration and approaches and doing a considerable amount of experimental



work on cadavera, a few cases were operated on and finally in May, 1939, a case was shown in the Section of Otology, Royal Society of Medicine, who after a five year interval since operation still retained a remarkable degree of restored hearing. Then came the war years which, while putting a stop to actual operative procedure, gave ample facilities for experimental work: the result being the adoption of a one stage procedure like Lempert's but with a post-aural approach like that of Sourdille.

Since 1939 considerable strides have been made: in the U.S.A. Lempert, Shambaugh and others have been hard at it. In this country, Simson Hall of Edinburgh, Cawthorne and Garnett Passe in London and various other workers have kept the ball rolling, while Holmgren and Sourdille on the Continent have not been idle. There has, moreover, been considerable liaison between workers in the different countries, and it may be said that the technique has crystallized out into a more or less standardized one stage procedure—the sole exception being that Sourdille still favours operating in two stages with a six months interval between them: instruments and operative steps are practically identical, but whereas in this country and on the Continent a post-aural approach is on the whole preferred, in the U.S.A. the transmeatal approach is the more popular.

The writer has just returned from attending the inaugural lectures and demonstrations on the surgery of otosclerosis given by Sourdille on his appointment to the Directorship of the Otorhinolaryngological Clinic of the Faculté de Médecine de Strasbourg. It was extremely interesting and admirably organized, and was very well attended by otologists from several parts of France, Switzerland, Holland and Belgium. We were given every facility to study and discuss every detail of his technique, examine his armamentarium, watch a demonstration operation by Sourdille on a cadaver, watch him perform the first stage on an actual patient, and finally to examine some cases operated on by him up to thirteen years ago and to test them in every way both with and without masking of the unoperated ear: so that one was able to form a very clear idea of the minutiae of his technique as well as of the ultimate prognosis.

It would appear then that there are actually three slightly different techniques in vogue:—

- (1) The one stage transmeatal operation of Lempert and Shambaugh.
- (2) The two stage postero-superior operation of Sourdille.
- (3) The one stage postero-superior operation favoured by Simson Hall and the writer.

It is not proposed to discuss the Lempert-Shambaugh operation here, as in the writer's opinion the access and exposure afforded are not so free as those obtained with a postero-superior approach and hæmostasis

## Labyrinthine Fenestration

appears to be less easy to secure. In fact it is like 'operating through a keyhole', and anyhow as a colleague has remarked "why make the operation more difficult?" Instead we shall confine ourselves to comparing the two postero superior operations.

1 *The two stage operation* Sourdille now operates under local anaesthesia. At the first stage he performs a modified radical mastoidectomy, preparing the tympanomeatal flap with great care with the aid of a magnifying loupe and paying particular attention to thinning it and trimming it to the required shape and size. He then removes the malleus head, but carefully conserves the incus as he considers that so doing increases the mobility of the flap after final fenestration. The flap is then carefully placed in position and tamponaded with paraffined gauze and the incision is sutured. He carries out frequent transmeatal dressings until healing is secured.

Six months or so later he carries out the second stage. He reopens the incision, makes a semicircular incision in the shrunken adherent flap postero superior to the torus of the external semicircular canal, raises the flap so devised and rolls it forward so as fully to expose the torus. Then using an operating microscope and with the aid of rasps of various sizes—rather like minute crochet hooks with straight back slanted chisel edges—he fenestrates the torus close to the dome of the vestibule, reapplies the flap and tamponades it in place with paraffined gauze. The incision is then sutured. Frequent transmeatal dressings are carried out until healing is secured.

Special points worthy of note are that Sourdille makes the postero superior skin incision with a diathermy cutting needle, arrests all hemorrhage immediately it occurs and carefully removes all bone fragments with forceps. He does not employ a saline stream as not using a drill there is no bone dust to remove. Moreover he ignores the question of serous labyrinthitis and it is probable that he is able to do so with impunity because he does not cover the fenestration with a freshly cut tympanomeatal flap but with a fully shrunken sheet of scar tissue of many months duration which is so avascular that capillary dilatation and increased capillary permeability just don't occur. He does not deliberately enchondralize the area around the fenestration site but on the other hand his rasping away of the bone until eventually the endosteum is exposed which he then carefully opens, secures this more or less automatically. He employs no prophylactic intramuscular penicillin prior to operation and finally unlike certain American workers he makes no extravagant claims to 80 per cent successes but like ourselves says that there is a fifty-fifty chance of success.

2 *The one stage operation* The question is can we hope to obtain as good results by the one stage procedure as Sourdille does by his two stage technique? In the writer's opinion we can—but the most meticulous attention to detail is absolutely essential if we are to avoid—

- (a) failure or
- (b) disaster

If however adopting the two year criterion we find that we cannot equal Sourdille's results in a reasonable proportion of cases it may be that we would be well advised to revert to the two stage technique.

## C. A. Hutchinson

For the benefit of those about to take up fenestration the following detailed account of the selection of patients, their preparation for operation, the actual operative technique and the after treatment adopted by the writer are given in full.

### Selection of Cases

This is of the utmost importance. There are in the writer's opinion three absolute contra-indications to operation :—

1. Practically complete or complete absence of hearing by bone conduction—indicating a hopelessly disorganized organ of Corti and/or spiral ganglion or cochlear nerve.
2. The presence of otosclerotic changes radiographically demonstrable in the actual bony wall of the external semicircular canal.
3. Cases with well marked alteration in tone of their voice—the significance here is probably the same as in (1) above.

Relative contra-indications to operation are :—

1. The presence of a low middle fossa and a forward lateral sinus, when it is impossible to secure the essential free access to the fenestration area.
2. Female subjects in any stage of pregnancy—distinct aggravation of the disease occurs at such times.
3. Subjects with low-grade mentality—in whom it is difficult if not impossible to re-educate their atrophic hearing centres.
4. Over age—the best results are obtainable in patients between the ages of 20 and 30 ; prognosis is less favourable between the ages of 30 and 40 ; while in patients over the age of 45 it is doubtful whether it is worth while operating at all: the explanation being that with advancing age the nerve of hearing gradually degenerates, while the hearing centre itself becomes atrophic from disuse and is therefore not re-educable.
5. Extreme deafness and/or high tone loss below ordinary speech levels. In America they are not so rigid in their views as to whether patients with a major degree of high tone loss should be operated on or not.

One can sum up by saying that the most suitable type for operation is the young, intelligent adult between the ages of 20 and 30, with audiograms showing a flat conduction deafness curve of more than 30 decibels, and more or less good bone conduction hearing.

### Preliminary Steps before Operation

1. Any septic focus in nose, paranasal sinuses, pharynx or nasopharynx must first be cleared up before the fenestration operation is attempted.
2. Reliable audiograms should be taken of both ears. The writer is indebted in this respect to the Acoustic Department of Messrs. Allen and Hanbury, who go to considerable trouble to carry out tests for him under identical conditions etc.

## Labyrinthine Fenestration

3. First-class bilateral radiograms of both petrous bones are required to show the position of the middle fossa and of the lateral sinus on each side.

4. Special angle radiograms of both labyrinth regions are required to show the presence or absence of otosclerotic changes in the region of the external semicircular canal. A radiological colleague kindly worked out these angles for the writer so as to give the maximum clarity. He employs the following :—

O-M line at right angles

Tilt of head 45 degrees

Tilt of tube 12 degrees to head.

### Operative Risks and Complications

1. *Suppurative labyrinthitis with the possibility of subsequent meningitis.* With modern aseptic technique this risk is negligible and the writer has never had a single case.

2. *Vertigo.* This may or may not occur, its duration is usually short and the response to therapy with luminal is satisfactory. It usually disappears in a few weeks, but in occasional cases may last a few months. However, even after its apparent disappearance, violent blowing of the nose or sneezing may produce temporary vertigo, and therefore some care has to be exercised to avoid doing either of these things when crossing a road.

3. *Facial paresis and paralysis.* Some operators have had this complication. The writer believes this to be due to frictional heat engendered during fenestration. Working as he does in a saline stream he has never had it occur; Simson Hall's experience is, he believes, similar.

4. *Further impairment of hearing.* This only occurs in some 2 per cent. of all cases and is therefore a very slight risk indeed.

5. *Death from heart failure.* This again has been reported but the writer has never seen it occur and believes it to be no greater risk in fenestration than in say a hernia operation so that it is a cause for headache to the anæsthetist rather than to the labyrinthine surgeon.

### Anæsthesia

A few operators favour local anæsthesia, the majority, however, are definitely in favour of general anæsthesia. In the writer's opinion the best form of this is Gas-Oxygen-Trilene. The operation is a long one taking 1 hour 45 minutes to 2 hours in all; throughout the whole of this period the patient must be "flat out" and immobile without the slightest variation in blood pressure with its resultant possible hæmorrhage into the fenestrated labyrinth—should this occur the operation is foredoomed to failure and the surgeon may as well go home, for the results are disastrous and final so far as the desired resultant improvement in hearing is concerned. The anæsthetist, therefore, has to be on his/her toes the whole time and it may definitely be stated that the anæsthetic should not be undertaken by any anæsthetist who has not had considerable experience with anæsthetics for labyrinthine surgery.

## Standing Ward Orders for Fenestration Patients

1. *Pre-operative Ward orders*

- (a) Admit by 5 p.m. the night before.
- (b) Routine pre-op. examination, urinalysis, etc.
- (c) All wax to be removed from ear selected for operation.
- (d) Prophylactic penicillin 20,000 units I/M three-hourly round the clock, starting at 8 p.m. and continuing up to and inclusive of 2 p.m. on the next day (day of operation).
- (e) Complete half-head preparation in a.m. (sticky plaster to hair margins for women).
- (f) Spirit preparation of shaved area and auricle—*no* spirit to enter external auditory canal.
- (g) *Fill* external auditory canal with Tinct. Merthiolate.
- (h) Cover with sterile gauze dressings and bandage in place.
- (i) Enema.
- (j) Nothing by mouth after tea and toast breakfast.
- (k) Pre-operative medication as selected by anaesthetist.
- (l) Theatre for 2.15 p.m.

2. *Post-operative Ward Orders*

- (a) Side boards for first 24 hours post-op.
- (b) Raise head of bed 12 inches for first 24 hours post-op.
- (c) "Special" nurse for first 36 hours post-op.—she must *not* leave the ward at all unless relieved first.
- (d) Nurse as far as possible on back with head fixed supine or (preferably) operated ear down and give bed-rest as soon as it can be tolerated.
- (e) Ward to be kept darkened and as quiet as possible first 36 hours post-op.
- (f) If vomiting more than slight, notify anaesthetist during first 24 hours post-op.
- (g) Coramine one ampoule if respiration falls below 12 or becomes shallow—and notify House Surgeon or Surgeon.
- (h) Report to Surgeon any (a) facial paresis, (b) spontaneous nystagmus, as soon as noted.
- (i) Moderate fluids and glucose only by mouth first 24 hours post-op.; then build up diet gradually.
- (j) Resume penicillin 20,000 units I/M three hourly round the clock as from 5 p.m. on day of operation for 24 hours; then refer to surgeon as to whether to discontinue.
- (k) Veganin for pain *pro re nata*; refer to surgeon if this fails to control.
- (l) Luminal in  $\frac{1}{2}$  grain doses for vertigo—but refer to surgeon if more than slight vertigo.
- (m) Vegetable laxative in evening after that of day of operation—*no* purgatives.
- (n) Pack over dressings if soaking through—but do *not* displace them.
- (o) Warn the patient not to touch bandages—if they tend to slip he/she must notify the nurse.
- (p) First dressing by surgeon on 8th day post-op.

# Labyrinthine Fenestration

## Instructions for the Patient

The following information and instructions are given to each patient

### i. *Information for the Patient*—given him/her at the Consultation

- (a) While we are not as gross optimists in this country as they are in the States, a review of statistics from all surgeons performing this operation, and including good as well as the poorest cases, shows that about 50 per cent of the patients receive permanent and practical hearing improvement from the fenestration operation

In your case the tests show —



You have a well functioning nerve of hearing and are a suitable candidate for the fenestration operation, always provided that radiographical examination does not negative this



Your nerve of hearing has been damaged to the extent that you are a border line candidate for the fenestration operation. If under these circumstances the maximum improvement is obtained from the operation serviceable hearing will be restored to you



Your nerve of hearing has been damaged beyond a point where the fenestration operation would be advisable

- (b) *Line of action to take if at first you decide against Operation* — You should have audiograms and examination by the Otologist once a year, when, if the nerve degeneration is progressing, you must decide once and for all whether or not to have the operation, otherwise it will be too late

### (c) *Risks etc (other than operative risks)* —

- (1) 2 per cent only show aggravation of hearing impairment
- (2) 5 per cent show facial paresis (weakness of the facial muscles) subsiding in a few weeks or months at the latest
- (3) There is the merest trace of a possibility of further nerve degeneration with advancing age
- (4) 10 per cent show osteogenesis (new bone formation)—this comes on mainly (82 per cent) within the first, the balance within two years after operation, so this is the vital period as regards failure or partial failure

### 2 *Instructions to the Patient as to Post operative Care*—given him/her on admission —

- (a) Expect post-operative dizziness or giddiness for first 4-6 days
- (b) As soon as it improves you will be allowed to get up, but you must always be accompanied at first to avoid falling
- (c) You will leave Hospital about 10th-14th day, but you will still be unsteady and should therefore be escorted
- (d) Two or three days after leaving hospital you should visit the otologist and should still be escorted

- (e) As a rule dizziness and unsteadiness will have disappeared one month after operation. In occasional cases slight unsteadiness on making sudden movements will be felt for many months to come.
- (f) Blowing the nose or sneezing may also cause momentary vertigo; therefore avoid these when crossing a street.
- (g) Smoking tends to increase vertigo; therefore curtail this strictly or (better) cut it out altogether for a time.
- (h) Report to the otologist about six times the first month starting (as mentioned above) (on the second or third day after leaving hospital; after the first month report once a week and later once a fortnight until the ear has completely healed.
- (i) Complete healing takes 6-8 weeks on the average—sometimes considerably longer.
- (j) At the second or third visit to the otologist the bandages will be removed and then a light plug of sterile cotton wool only will be employed; this should be changed twice a day or more often if it becomes moist. You can introduce this yourself.
- (k) When the ear stops discharging by day, it will only be necessary to introduce the cotton wool plug at night.
- (l) Dry secretions on the outer ear can be cleaned away with cotton wool moistened with peroxide; but let *no* peroxide or water enter the ear until it has quite healed.
- (m) When the preliminary packing is removed from the ear at the first dressing while you are still in hospital (about a week after operation) the hearing in the operated ear will often be found to be as poor as, or poorer than, it was before operation; after another week or so however it begins to improve slowly—so don't be disheartened. The hearing improvement reaches its peak in two to six months; moreover, the hearing when it first returns will be distorted but after a few weeks becomes clear and natural. Lastly, the hearing in the unoperated ear will be found to improve a bit; this is due to re-education of the hearing centre which has become lazy.
- (n) If after being dry, the operated ear begins at any time to "weep" again see the otologist at once.
- (o) Audiograms should be repeated six months after operation, at the end of the first year, and at the end of the second and fifth years.
- (p) You must not go bathing until the ear is quite dry; and then only if a vaselined ear-plug is worn and a bathing-cap with ear-flaps (this is because entry of cold water into the operated ear might cause severe and dangerous dizziness).
- (q) Owing to a slight tendency to dizziness, be very careful when climbing ladders etc.
- (r) Air travel will be harmless but should be avoided if you are suffering from acute head cold.
- (s) Once the ear has healed have it cleaned out by the otologist once every 6-12 months because of an increased tendency to accumulate wax.
- (t) In any case, return to the otologist once a year for testing for the first five years after operation.

# Labyrinthine Fenestration

## Theatre Lay-out

The following diagram shows a suitable theatre lay-out. Special points are the following—

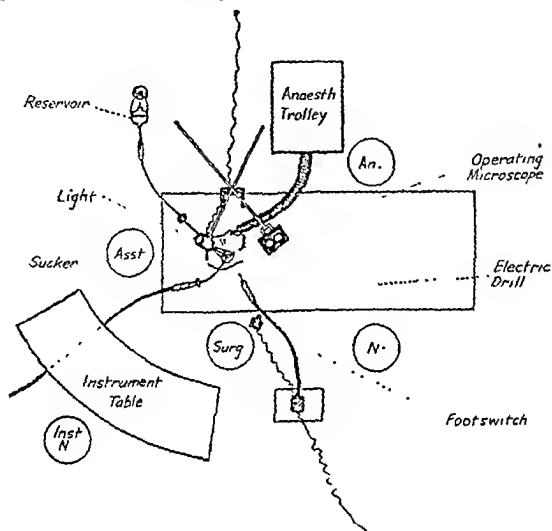


FIG. 1.—THEATRE LAYOUT FOR FENESTRATION.

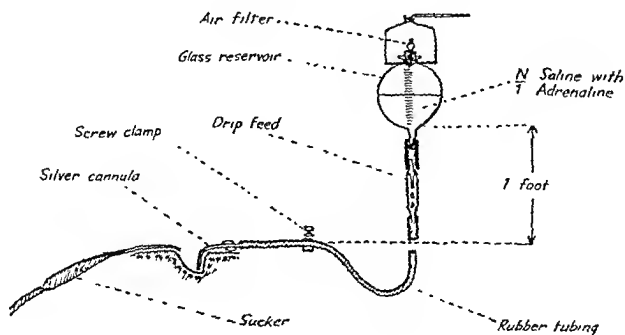


FIG. 2.—CONTINUOUS IRRIGATION APPARATUS



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- (1) Operating microscope and lamp are provided with a sterilizable aluminium hood each.
- (2) The electric drill flex is fitted with a sterilizable sleeve.
- (3) Special requirements in the Theatre over and above the usual dressings etc., are :—
  - (a) 1/1,000 Tincture of Merthiolate.
  - (b) Zelex.
  - (c) 10,000 unit penicillin solution.
  - (d) Kleen-oil and Lubrisol.
  - (e) N/1 Saline slightly above blood temperature.
  - (f) 1/1,000 Adrenaline solution.
  - (g) Surgical spirit.
  - (h) Six gallipots.
  - (i) Bipp.
  - (j) Sterile paraffin.

### Sterilization of Instruments

1. All non-cutting instruments are sterilized by boiling.
2. All cutting instruments and burrs are soaked in surgical spirit for twenty minutes, then washed in sterile water before use.
3. Caps, masks, gowns, gloves, towels, sleeve for the drill flex, ligatures and sutures are sterilized in the usual way.
4. Metal hoods for operating microscope and operating light are sterilized by boiling.
5. The drill handpiece is sterilized by boiling ; then run for five minutes each successively in (a) Lubrisol (b) Kleen-oil—both of which have themselves been autoclaved.
6. Zelex is sterilized by dry heat in plugged test-tubes.

*Note.* The Zelex is prepared by mixing it with equal parts by weight of a sterile 10,000 unit penicillin solution ; when, after three to five minutes interval to stiffen, it is ready for use.

### Technique

A large pad of wool is placed in the angle between the head and the shoulder. The operating light is carefully centred on the operation ear, locked in position, and turned on. Sterile jackets are then applied to the light, drill and operating microscope. The sterile towels are then fixed in position with mastisol or towel clips.

#### *Phase I*

A curved incision is made through the scalp with a small round-bellied scalpel from a point above the anterior border of the helix round behind the ear as far as the mastoid tip and carried down to the bone. All bleeding points are ligatured. The periosteum is then raised with an elevator and retracted towards the ear until the suprameatal spine of Henle is fully exposed.

An incision is made through the membranous external meatus in the plane of the skull surface from a point near the bottom of the posterior meatal wall,

## Labyrinthine Fenestration

across this wall and the roof, to a point slightly beyond the junction of the roof and the anterior wall. From each end of this incision a further incision is carried down at right angles to it to a point in each case just short of the line of attachment of the tympanic membrane. All bleeding points are ligatured.

A Mollison retractor is now introduced, the tongue of it entering the external meatus through the first meatal incision. Minute gauze tampons are placed in the external meatus to protect the tympanic membrane. With fine elevators and with the aid of Weiss magnifying lenses the membranous external meatus between the two vertical incisions is carefully stripped from the bone as far as the annulus tympanicus and turned down into the external meatus and covered with a small protective gauze tampon.

*An epitympano mastoidectomy is then performed and the facial ridge is lowered as far as the ' Bridge*

The tampons in the meatus are removed and the membranous external meatus and membrana flaccida with which it is in direct continuity, are carefully stripped intact throughout the full extent of the meatal flap from the annulus tympanicus. A tampon is introduced to protect the flap and the "bridge" is then carefully removed. The malleo-incudal and incudo-stapedial joints are incised with a paracentesis knife and the incus dislocated and gently removed. The superior ligament of the malleus is then divided and the loop of a thin special snare passed over the malleus head to lie around its neck, then with vernier screw control the loop is tightened until the malleus neck is severed. Alternatively the malleus neck can be severed with the writer's pattern guillotine. The malleus head is removed. In this operation the utmost care must be exercised to avoid "jump" and trauma to the tympano-meatal flap. The tympano-meatal flap so devised is then turned into the external meatus over small gauze tampons.

Any bone flakes which may have separated from the annulus tympanicus are carefully removed with fine forceps and manicure scissors from the outer surface of the tympano-meatal flap. The flap itself is then carefully trimmed with the scissors to render it as thin as possible and carefully shaped so as to fit accurately into the fenestration area. It is then turned downwards and forwards into the external meatus between adrenalized gauze tampons to keep it ischaemic.

A further flap is then cut from the external meatus and sutured to the inner surface of the anterior margin of the original curved skin incision.

### *Phase II*

The Weiss lenses are now discarded and the operating microscope swung into position by the assistant. The assistant next fixes in position the fine silver nozzle of the irrigation apparatus so as to deliver a stream into the depths of the wound. The saline-adrenaline stream is then turned on and all overflow is removed by the assistant with a sucker from the surface of the wound.

The site of the fenestration should be carefully selected and should lie on the torus of the external canal as near its junction with the vestibular dome as possible.

The surroundings of the fenestration site are enchondralized with a medium sized dental cutting burr in the electric drill handle and then carefully polished.

off with the polishing burr. This enchondralization and polishing off is repeated until the appearance of a bluish-grey oval patch in the centre of the area indicates that the endosteum has been reached. The drill is then discarded and starting on the side of the concavity of the external canal the endosteum is carefully removed from the fenestration site over an oval area roughly seven to nine mms. long by one to two mms. wide with fine dental picks. Any under-lipping of the fenestration margin being scrupulously avoided in order to avoid giving play to the osteogenetic properties of the subjacent cambian layer; the greatest care being also taken to avoid traumatizing the membranous canal which appears like a white thread in the perilymph of the torus under the fenestration.

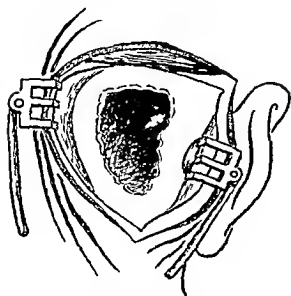
The tympano-meatal flap is then cleared of its adrenalized tampons and turned back so as to fit snugly over the fenestration area. During the last five minutes a supply of Zelex has been made up by an assistant with equal parts by weight of a 10,000 unit penicillin solution. A small wedge of this, about the size of the old threepenny bit, is then pressed home over the flap and smoothed off with a penicillin-moistened finger. A basket of paraffined gauze is applied over this and a fair sized wedge of Zelex pressed down into it and again smoothed off with a penicillin-moistened finger. A second basket of paraffined gauze is then introduced and a final thick wedge of Zelex pressed home, heaping it up well above the contour of the head. Sterile dressings are then applied over the Zelex pack in the open wound and fixed in place with firm bandaging. The patient is now returned to bed, and the head fixed so that for the first seven post-operative days he lies on the operated ear.

The following brief points are worthy of note :—

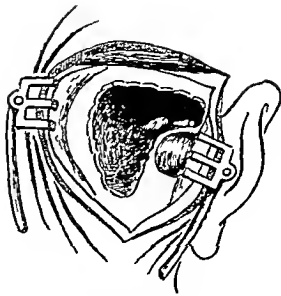
1. Carrying forward the first meatal incision onto the anterior wall of the external meatus and then making a second incision at right angles down to the attachment of the tympanic membrane ensures that the thinner roof and anterior wall of the membranous external canal are incorporated in the flap rather than the thicker posterior wall.
2. Thinning of the flap was adopted so as to bring the epithelium of the flap with its inhibiting effect on osteogenesis to lie as close to the surface of the fenestration as possible.
3. Zelex is introduced under pressure to keep the flap capillaries squeezed empty of blood, so lessening the tendency to serous labyrinthitis.
4. The use of paraffined gauze baskets ensures easy removal of the Zelex pack in sections at the first dressing.
5. Fixation of the patient's head so as to lie on the operated ear ensures that the cochlea of the operated side is at all times above the fenestration, so preventing gravitation of red blood corpuscles and serum into the cochlea.

## After Treatment

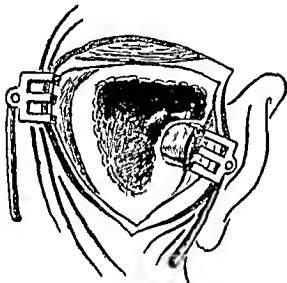
The first dressing is carried out by the surgeon on the eighth day when the Zelex pack is removed, all save the minute wedge of it in contact with the flap: the cavity is then packed with slightly paraffined sterile gauze brought out through the meatus and the postero-superior wound is sutured.



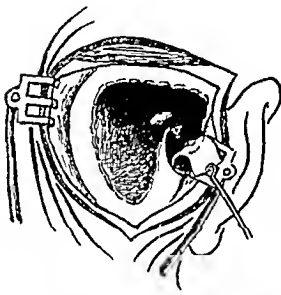
a Schwartz Mastoidectomy



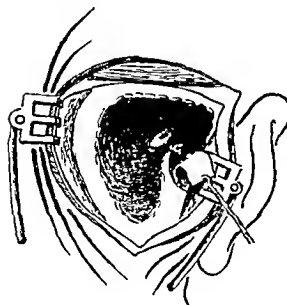
b Modified Radical



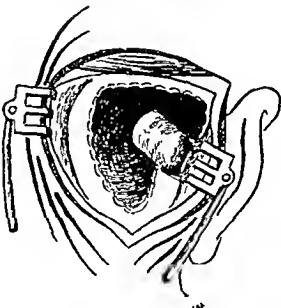
c The Flap cut Facial Ridge lowered



d Tympanomeatal Flap raised and retracted Facial Ridge lowered Bridge removed Incus removed Malleus Head removed



e Fenestration completed



f Tympanomeatal Flap applied

FIG 3

Fenestration—Postaural Technique



# Labyrinthine Fenestration

On the 10th day the gauze packing and the remaining Zelex wedge are removed transmeatally the cavity is painted out with 1/1,000 tincture merthiolate, insufflated with sulphathiazole and penicillin powder (10,000 units per gramme) and lightly packed with sterile gauze

On the 14th day the merthiolate, sulphathiazole and penicillin insufflations and the light packing are repeated

On the 21st, 28th and 42nd days the cavity is painted out with 2 per cent aqueous solution of Methylosaniline chloride Thereafter this treatment is repeated once a month until the cavity is completely epidermized and healed

The patient gets up about the 6th day and leaves hospital about the 12th to 14th day on the average He visits the otologist on the 17th, 21st and 28th days and thereafter once a fortnight until complete healing is secured the bandages are discarded after the 21st day From the 21st day onwards the light gauze packing is discontinued and instead light sterile cotton-wool packs are employed, these are changed once or twice a day and can be introduced at home

## Causes of failure

1 *Retraction or "Decollement"*, as Sourdille calls it, of the flap—with dead-space formation interfering with the proper functioning of the new membrane With modern technique and the polishing off of the bone around the fenestration better apposition of the flap is secured, and this therefore rarely occurs now a days

2 *Keloid Development* In the present state of our knowledge we are apparently powerless to prevent this fortunately it *very* rarely occurs

3 *Secondary Ulceration of the Flap* Probably invariably of septic origin I am glad to say I have never seen a case, and for this I am sure we are indebted to the orthopaedic preparation of the patient and the rigid aseptic operative and post operative techniques

4 *Injury to the Membranous Labyrinth* This risk has been reduced to the minimum thanks to the adoption of the operating microscope and the free and tangential access provided by the postero superior approach, in contrast to the vertical and restricted access afforded by the transmeatal approach which Lempert and certain other surgeons favour Another factor in this reduction is the fact that when the endosteum is being opened at the actual fenestration it is approached from the side of the concavity of the external canal where there is more room for instrumentation than would be the case if the approach was from the side of the convexity

5 *Acceleration of the Otosclerotic Process* with degeneration of the organ of Corti This is countered by refusing to operate at all events for the time being, on any female subject in any stage of pregnancy

6 *Failure of Atrophic Hearing Centre as a result of disuse to recover its function* The careful selection of patients for operation and the inflexible rejection of mentally sub normal subjects, of those showing change in tone of

their voice and of those over the age of 45 have reduced the incidence of this cause of failure to a very low level.

7. *Osteogenesis* and closure of the fenestration by new bone formation. This, it must be admitted, occurs in some 10 per cent. of cases regardless of what steps are taken to try and prevent it. Its occurrence, however, is considerably less common than formerly, thanks to :—

- (a) The new technique with its removal of all bone chips by the saline-adrenaline stream.
- (b) The polishing off of the margins of the fenestration and its surrounds.
- (c) Securing what Shambaugh calls "enchondralization" of the fenestration surrounds.
- (d) The careful prevention of any underlipping of the fenestration so avoiding exposure of the cambian layer with its vigorous potential osteogenetic capacity.
- (e) Taking care to thin the flap as far as possible so that the squamous epithelium with its inhibitive action on osteogenesis shall come to lie as close as possible to the surface of the fenestration.

8. *Serous Labyrinthitis*. With the continual improvement in technique first one and then another of the causes of failure have been eliminated so that now-a-days serous labyrinthitis comes to occupy a considerably more prominent position. It can be recognized by the occurrence of spontaneous nystagmus, of which the quick element is usually directed towards the un-operated ear, but occasionally is of vascular type with a rhythm synchronous with the pulse.

The experiments of Shambaugh on monkeys show clearly that this serous labyrinthitis is due to the presence of red blood corpuscles and serum in the perilymph space under the flap. The problem of how to prevent it occurring crystallizes out into how to reduce bleeding during operation and in particular how to prevent inflammatory reaction in the flap during the immediate post-operative period.

It is possible to render the fenestration area practically bloodless—quite apart from arresting the hæmorrhage during operation as it occurs—if the actual fenestration itself is performed in a continuous controllable stream of physiological saline to which a few drops of adrenaline have been added. When dealing with the plethoric type, he can be placed on "coagamine" or some other parenteral hæmostatic agent, or on a course of calcium gluconate and vitamin D. Shambaugh himself goes further and removes some 500 cubic centimetres of blood three days before the operation in order to stimulate the hæmopoietic activity of the marrow.

In order to prevent inflammatory reaction in the flap one must realize that it is due to the liberation of histamine and histamine-like substances by the inevitable trauma to the flap in its actual preparation, resulting in local capillary dilatation and increased capillary permeability, as a result of which the red blood corpuscles and serum pour out into the connective tissues of the flap and the perilymph space below it in the region of the fistula. This inflammatory reaction ceases in some four days or so; accordingly, if one can keep the capillary vessels squeezed dry and empty during a few days after operation, its occurrence can be prevented altogether.

If this inflammatory reaction is slight it may resorb completely. If, on

# Labyrinthine Fenestration

the other hand, it is allowed to develop, an arachnoiditis commences in the region of the fistula which may terminate in fibrosis, permanent organization and new bone formation. But what is more important is the fact that a number of red blood corpuscles and serum gravitate to the more dependent parts of the cochlea where there are no arachnoidal fibres in the scala vestibuli and the scala tympani, so that the corpuscles come to lie actually against the delicate walls of the membranous labyrinth, without penetrating the latter but causing an irritative exudate to develop in the actual cochlear duct. This, if severe results in adhesive degeneration of the organ of Corti—Reissner's membrane, the tectorial membrane and the hair cells becoming stuck together and the cells themselves degenerating.

The capillary vessels can be kept empty by applying firm bandages over tampons of sea-sponge, sorbo sponge or, as the writer prefers, Zelex. Lastly, the gravitation of blood elements to the cochlea can be prevented if the patient's head is fixed for several days after operation either looking directly upwards or actually resting on the operated ear, in which position the cochlea is at all times lying above the level of the fistula.

## Prognosis as regards Hearing

Operators who employ local anæsthesia report that the hearing may be acute immediately after operation, but that during the following week it declines to about the level at which we who favour general anæsthesia find it at the first dressing, when it may be as poor as, or poorer than, it was before operation. At about the end of another week, however, it usually begins to improve slowly and reaches its peak in from two to six months. The regained hearing tends to be distorted at first, but in the course of a few weeks it becomes clear and natural. A general survey of the results secured by all surgeons performing fenestration shows that in carefully selected cases there is a fifty-fifty chance of a 25 to 35 decibel improvement in hearing, and such improvement if retained for one year will probably, and if retained for two years will certainly, be permanent. An audiogrammatic reading of a case taken 3½ months after fenestration follows on the next page.

## General Systemic Treatment

Since otosclerosis is a local manifestation of a general disease process systemic treatment should be practised both before and after operative treatment in the hope of at least checking the progress of the disease and preventing further degeneration of the cochlear mechanism and/or the hearing centre.

1 The general health should be maintained, particular attention being paid to the energetic treatment of any anæmia. This is most important.

2 Any evidence of endocrine imbalance should receive due attention. Pituitary extract ½ grain daily is well worth trying. Then wait a month and



# C. A. Hutchinson

LINE 0 = AVERAGE NORMAL HEARING

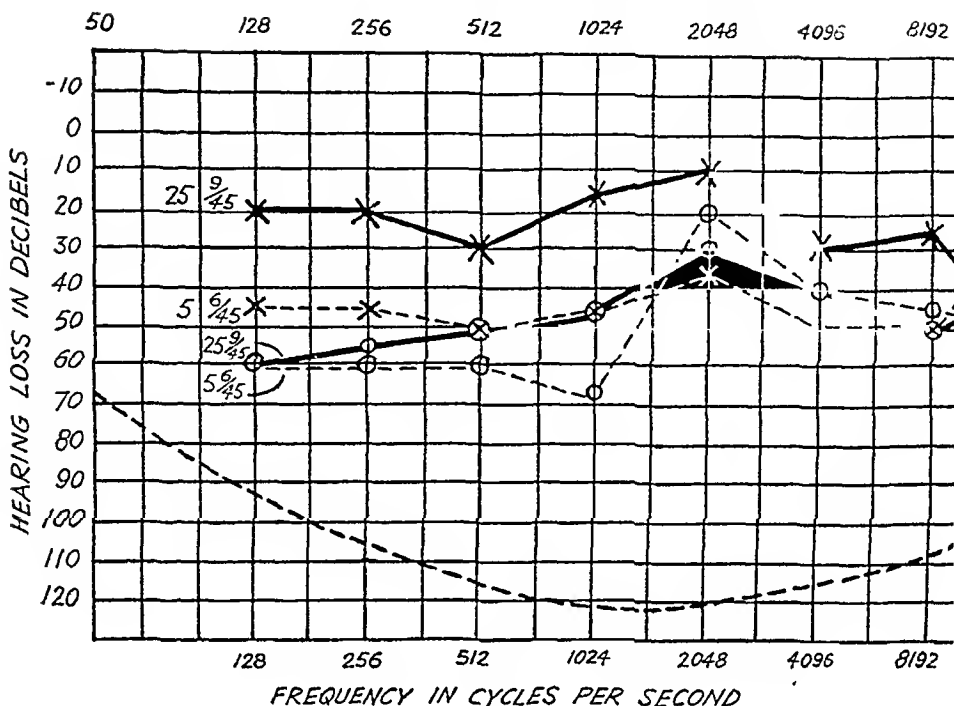


FIG. 4.

## 6A AUDIOMETER TEST CHART.

Interrupted lines - - - Hearing levels before Fenestration.

Continuous lines—Hearing levels after Fenestration.

X—Left ear.

O—Right ear.

repeat. Adrenal extract has its advocates. Some authorities favour the following course :—

Zinc Phosphide	...	1/10 gr.
Lecithin	..	4 gr.
Calcium Glycerophosphate		4 gr.

One cachet of the above three times daily for three months ; then interrupt for a month giving in the interim four injections of Martindale's ampoules of pituitary 1 c.c. at a time. This full course to be repeated three times.

## Arguments Pro and Con Operation

1. It has been stated that since otosclerosis is a degeneration process, surgical measures can lead to no benefit. The answer to this is that surgery aims at improving the hearing and not at curing the disease.

2. Operation, it is objected, involves risk to hearing and life. As regards the first, the hearing powers are already to all intents and purposes useless and

## Labyrinthine Fenestration

will become even more so unless something is attempted. The danger to life is almost nil, there have been practically no fatalities in the hands of labyrinthine surgeons of repute. In fact now a days it is far more dangerous to travel by train or car than to have a fenestration performed.

3 Finally, it is argued that now-a days when bone conduction hearing aids have attained such a high level of excellence and can confer such benefit, no risk whatsoever is justifiable. To this the answer is that otosclerosis is a progressive condition, therefore sooner or later the time comes when the hearing aid, at first so efficacious, is no longer of the slightest use to the disappointed and disillusioned patient, who moreover is now far deafer than he was before, besides being past suitability for operative procedure, on the other hand a successful operation in the first place confers improvement which is lasting.

In conclusion the writer would like to stress the need for recognizing the fact that labyrinthine fenestration should not be embarked on lightly by all and sundry. The technique should first be fully mastered by studying the methods of those who have made a regular practice of the procedure and then by adequate experimental work on cadavera.

The careful selection of cases, the thorough preliminary drilling of the theatre team, the orthopædic preparation of the patient, a completely adequate armamentarium, the most rigidly aseptic operative and post-operative technique and the most meticulous attention to detail at operation are all factors of the utmost importance if success is to be attained. Moreover, since closure of the fenestration as the results of osteogenesis may occur up to two years from the date of operation, this period of time should in every case be allowed to elapse before attempting to assess such success.

Sourdille's words "Il s'agit d'un sujet de grand avenir" in a letter to the writer in January, 1940, express the writer's firm opinion regarding fenestration. "Fools rush in where angels fear to tread", it would surely be a thousand pities if a spate of careless, clumsy and foolhardy attempts at the procedure produce such a crop of lamentable failures as can only bring this valuable operation into disrepute.

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Since the above went to press the writer has studied the description of the new transtympanic approach advocated by Popper of Johannesburg, but considers that it is still so very much in the experimental stage and unsupported by final post-operative results that it is difficult to assess its true value, moreover, while it would certainly seem to merit careful study and trial, it is certainly premature to "scrap", as Popper suggests, the "surgical absurdity" of the postero-superior transmastoid approach, which whatever its disadvantages has indisputably yielded a reasonable proportion of successes out of several hundred operated cases.

# ACUTE OTITIS EXTERNA IN INDIA

J. V. CLARK (Tunbridge Wells)

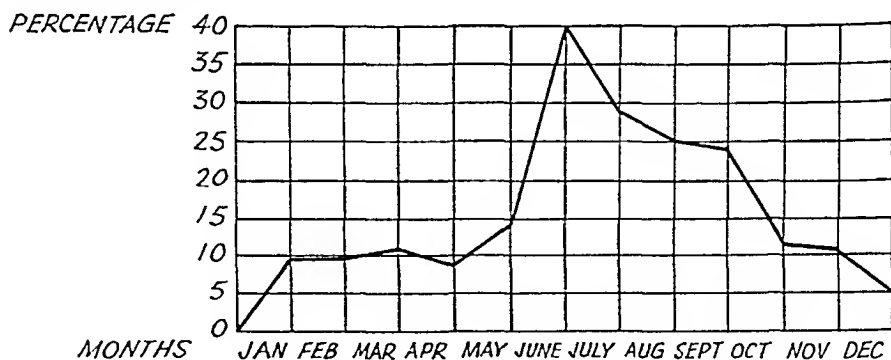
OTITIS EXTERNA in India is an extremely common condition, amongst both Europeans and Indians—how common is probably not fully appreciated, and I think that the figures published from the Army E.N.T. Centre in Secunderabad during the course of one full year, together with detail of clinical observations, bacteriological findings, and methods of treatment adopted may be of interest.

## Frequency

During the year commencing April, 1945 to April, 1946, the total of new E.N.T. cases seen of all types, including War casualties, was 3,165. Of these, 525 were cases of otitis externa. This gives a percentage of 16.4 per cent., which is a strikingly high proportion and is, I think, accounted for largely by climatic conditions.

## Ætiology

A graph designed to show the monthly percentage of otitis externa to all other E.N.T. cases is produced below :—



This shows a sharp rise during the months of May to October, i.e., the hottest months. The June temperature reaches about 114° F. and is the beginning of the Monsoon, with its increased humidity. Naturally, during these months many more people indulge in swimming, but this is far from being the complete explanation, as quite half the patients give no such history, and sweating alone suggests itself as the most important ætiological factor. Sweating results in the meatal canal becoming moist and this, together with warmth, offers a suitable nidus for infection to

## Acute Otitis Externa in India

develop I felt it was important to establish if organisms producing otitis externa were normally present in the ear, and merely flourished and became pathogenic when conditions suitable for their growth presented, or if organisms were introduced in the presence of suitable growing conditions. The latter has proved to be the case, as will be seen from the bacteriological investigations detailed later

### Clinical Types of Acute Otitis Externa encountered

- 1 *Œdematous*
- 2 *Purulent*
- 3 *Granulomatous*
- 4 *Membranous*
- 5 *Hæmorrhagic or Bullous*

The furuncle so commonly encountered in temperate climates is very rarely seen

#### *Œdematous*

This is the commonest type of all—the meatal skin is diffusely involved, becomes very swollen resulting in meatal occlusion of varying degree—often severe. Discharge as a rule, is scanty. Pre-auricular and upper deep cervical adenitis is usually present, producing swelling anterior to, and below the ear. In more severe cases, periostitis develops with resulting œdema over the mastoid process which characteristically obliterates the retro aural groove first. Sometimes, œdema becomes marked and widespread, causing outward and forward displacement of the pinna. Symptoms are apt to be severe. Toxic signs are variable but usually mild. Pain on the other hand is acute and the pinna becomes tender to all movement. Tenderness is marked in the pre auricular region and in the site between the mastoid tip and ascending ramus of the mandible. Eating is painful, as jaw movement, particularly biting, causes pressure to be communicated to the meatal wall, with resultant pain.

Tenderness over the mastoid bone is rarely present even though œdema from periostitis is marked.

#### *Purulent*

This type is common, but signs and symptoms are quite different from the œdematous type. The meatal skin becomes raw looking, but is not swollen. Most commonly, the deeper parts of the meatus are alone involved. Discharge is rather more apparent than in the œdematous type but is never copious, and is of a thick creamy consistency. This discharge rarely flows from the meatus and is only noted on otoscopic examination. Symptoms are very mild—usually the patient complains merely of irritation and a wet feeling in the ear, perhaps scanty discharge from the ear.

*Granulomatous*

This type of otitis externa is really a more advanced stage of the purulent type. The same raw skin without swelling, the same scanty creamy pus is present, but associated one finds granulations present. These granulations take two forms, either a sessile plaque attached to the outer surface of the drumhead itself, or small pedunculated masses arising from the meatal walls—usually in the deeper parts of the meatus adjacent to the drum. Here they may arise from any point on the circumference of the meatal wall. Occasionally they are found in the outer third of the meatal canal, even though the main seat of infection would appear to be more or less confined to the deep meatus. The peculiar stalked nature of these granulations is striking, but can only be demonstrated by moving them with a probe.

*Membranous*

This is a rare type, of which only two cases were seen in this series, and is difficult to differentiate from certain types of self-inflicted injury by chemical agents.

The meatal skin is swollen, usually occluding the lumen. The surface looks grey and "sloughy" but the membrane cannot be detached at this stage. There is an associated scanty watery discharge. Pain and tenderness are marked, but, unlike the oedematous form, pre-auricular and upper deep cervical adenitis are not present. After 5 to 7 days the membrane separates and can be drawn out as a complete cast of the meatus, leaving a patent lumen. The residual lining is only mildly raw and heals within 2 or 3 days.

*Hæmorrhagic or Bullous*

This is a most interesting type of otitis externa, quite different from types previously discussed and absolutely characteristic in its signs and symptoms. It appears to be seasonal (April to August), and I, personally, have never seen a similar condition in England.

The patient has a sudden onset of *severe* pain in one or both ears, followed after 6 to 12 hours by a discharge of pure blood from the ear, though the pain is not relieved by this discharge. Apart from pain, the patient is usually fit—no cold, no sore throat, no fever, no loss of appetite. The ear is not tender to touch, and there is no surrounding pain or tenderness. There are no associated neurological signs. Examination of the ear shows one or several hæmorrhagic bullae on the meatal wall and occasionally involving the drumhead itself—this is very much the same as seen in cases of influenza, except these bullae are much larger, being about the size of a split pea. It is the rupture of one of these bullae which causes a discharge of blood enough to trickle down the face, giving some indication of their size. At first, the surrounding meatal skin is

# Acute Otitis Externa in India

not inflamed ; the drumhead is normal and the hearing is not impaired. Later, there is some degree of secondary infection, with resulting meatitis and often the drumhead becomes congested, and, in a few cases, an effusion has developed in the middle ear. Never has middle-ear suppuration supervened.

Whether the above clinical picture is only found in certain areas of India, I cannot say, but I suspect this to be the case, as no cases were noted in Bangalore Clinic during the peak months (April to August, 1946).

## Bacteriology

It is usually stated that the acute lesions of the external auditory meatus are due to staphylococcus or streptococcus—the staphylococcus producing the localized lesion of a furuncle and the streptococcus producing the diffuse lesion of acute otitis externa of the œdematous type.

Though more true of temperate than tropical or sub-tropical climates, I doubt if it is ever constant. Certainly the results obtained on 100 consecutive cases in Secunderabad showed it quite untrue.

The following tables summarize results (bullous otitis externa is not included)

TABLE I.  
CULTURES FROM MEATUS IN ACUTE OTITIS EXTERNA

Analysis of organisms present in 100 cases of Acute Otitis Externa						
	Pyocyanus	Proteus.	Staph.	Strep	Col	Diph.
Pure Culture	40	7	4	0	1	0
	24 x ————— x					
			10 x ————— x			
Mixed Cultures			8 x ————— x			
x ————— x			4 x ————— x			
		2 x ————— x				

TABLE II.

CULTURES FROM NORMAL EXTERNAL AUDITORY MEATUS.

Analysis of organisms present in 24 apparently normal meati. (Culture swab dipped in broth and then meatal smear taken.)									
	Pyocy- aneus.	Pro- teus.	Staph. alb.	Staph. aureus.	Strep.	Coli.	Diph.	B. Subt.	No Growth.
Pure Culture	Nil	Nil	7	4	Nil	Nil	Nil	Nil	9
	x — I — x								
Mixed Culture			x — I — x						
	x — x		x — I — x						
		x — I — x							

A close analysis of these tables produces the following significant facts :—

(a) *Pyocyaneus* is by far the commonest organism present in acute otitis externa, accounting for 40 per cent. of cases in pure culture and another 30 per cent. in mixed culture. It will be noticed that, in the series investigated, *pyocyaneus* was not found in pure culture in the normal meatus and was only present in mixed culture in one case. This observation, coupled with the fact that over 30 per cent. of normal meati proved sterile, would suggest that organisms present in the meatus are not causative. It has long been considered that the *pyocyaneus* is non-pathogenic. Recently, several workers in India have conclusively proved while studying penicillin therapy that the *pyocyaneus* organism must be recognized as a true pathogen in wounds, and, obviously, the ear is no exception.

(b) The organisms most commonly blamed for acute otitis externa account for a very small proportion in pure culture, i.e., staphs. 4 per cent. and streps. nil, though they do come second and third in the list in mixed culture, with staphs. present in 18 per cent. and streps. in 12 per cent., of which 10 per cent. are mixed staph. and strep. alone. The above figures naturally are of great interest when considering penicillin as a therapeutic agent.

## Acute Otitis Externa in India

It is interesting to note that in a similar bacteriological study of acute otitis externa by Quayle, A A M C, amongst Australian troops in New Guinea (*Med J Australia*, 11, 228-231, September 2nd, 1944) the same high incidence of pyocyanus infection was found, i.e., 51 per cent in pure culture and 14 per cent in mixed culture. This organism did not occur in any of the normal ears examined.

Now, a point I would like to stress at this stage is the fact that the organism present did NOT appear to be constant for any one clinical type of otitis externa. From typical cases of oedematous lesions every combination of organisms was found and pure pyocyanus in not a few. This, from the point of view of treatment, was apt to be confusing but will again be discussed under the heading of "Treatment". The bacteriology of bullous otitis externa is dealt with separately, as in the series of 12 cases seen during the one year, cultures were only made in 4. In these cases a swab was taken from the meatal wall, and a broth culture taken from a bulla by pricking it with a sterile needle, and then dipping the needle in broth. All the broth cultures, i.e., bullae, proved sterile. From the meatus two swabs proved sterile and the other two produced —

(a) *Staph. alb.*

Gram —ve bacilli

(b) *Pyocyanus*

Obviously no conclusions can be drawn from this tiny series and it was hoped further studies would be possible this season. Unfortunately, the ENT Centre was moved to Bangalore, where the climate is cooler, and no cases were seen.

### Treatment

In this department, treatment has been reduced in principle to a simple routine common to all types of cases, and it is hoped the following reasoning will justify the practice. With the many hundreds of cases passing through the department, it was an easy matter to give every suggested treatment a fair trial and to judge efficacy by results. One by one alternatives were rejected in favour of the present routine, which is as follows —

#### Stage I

Cleaning of the meatus—this is all important and must be painstakingly thorough. All discharge is removed with wool mops, particular attention being paid to all debris partially adherent to the meatal walls or to the outer surface of the drumhead. In some cases it is easier to syringe away this debris than to mop it clean, however, if syringing is employed, the meatus must be very carefully dried out afterwards with wool mops. In the case of the granulomatous type of otitis externa, the pedunculated granulations must be picked away with aural forceps. No anaesthetic is necessary, for, provided manipulation is gentle and the



adjacent meatal wall is not pressed upon, the pain is negligible. Any bleeding is controlled by wool or dry gauze, which is introduced for 5 to 10 minutes.

Once the meatus is THOROUGHLY clean, Stage II, of the treatment is carried out.

### *Stage II*

Insufflation of calcium penicillin and sulphathiazole powder, 5,000 units penicillin per gramme.

This insufflation is carried out under direct vision and is no more than a frosting of the surfaces of the meatal wall and drumhead. The above two stage treatment is a daily routine and it must always be thorough. Most cases clear up dramatically and are usually cured in from two to seven days.

The one exception to this routine is the case where meatal swelling is so marked as to occlude, or largely occlude, the lumen. Obviously, the treatment is then impracticable and the meatal swelling has to be reduced first. The reduction in swelling is achieved by carefully introducing a small wick (slices cut off rolled bandages) soaked in 8 per cent. aluminium acetate. This may have to be renewed after 24 hours, but it is rarely necessary longer than 48 hours. Once the lumen is re-established, the penicillin and sulphathiazole powder is insufflated as per routine. Now the obvious criticism of the use of calcium penicillin and sulphathiazole, is that bacteriological statistics have already shown that the potentially sensitive organisms are only present in 20 per cent. in mixed cultures and 14 per cent. in pure cultures. (Staph. pure 4 per cent. mixed staph. and strep. 10 per cent.) Although the powder is not always "specific" it does keep the meatus dry, and, provided the meatus is kept dry, the non-sensitive organisms should not thrive, as they need moisture.

The dosage of calcium penicillin was arrived at by assessing how much powder per patient was used on the average. By weighing the insufflator before and after use on 50 consecutive ears, the difference in weight worked out to 2 grains per ear, and the dosage of penicillin, therefore, was approximately 700 units. This is considered adequate over such a small area for twenty-four hours. Sulphathiazole was chosen as the vehicle not so much because of any specific action on organisms present, but because it is not highly soluble and would keep the meatus dry for 24 hours. When penicillin powder alone was used, the ears were found to be discharging again as soon as two hours after treatment. This proved equally true with boric powder, due to high solubility. Solutions of penicillin proved a failure. Even when culture had originally shown a pure staph. or staph.-strep. infection present, an initial improvement clinically was shortly followed by relapse, and pyocyanus found to be present. This I considered due to the wet method of treating an ear, which

## Acute Otitis Externa in India

I think should be condemned in a country where pyocyaneus is so rife. It is felt that the empirical use of this powder is therefore fully justified as culture reports take 48 hours before return, and in many cases the patient can be cured in this time.

In the case of bullous otitis externa, it would appear more sensible not to rupture the bullae as is frequently advocated, as the bloody medium resulting lends itself to further secondary infection.

Only one case of sulphonamide sensitivity was encountered in this series of cases. However, as recent reports have shown that sulphathiazole is more liable to produce skin sensitivity than sulphadiazine in the proportion of 13:1, it would perhaps be safer to substitute sulphadiazine for sulphathiazole, while retaining the original dosage of 5,000 units calcium penicillin per gramme of sulphonamide.

### Summary

A series of 525 cases of acute otitis externa, forming 16.4 per cent of all new E.N.T. cases seen during the course of one year at an Army E.N.T. Centre in Secunderabad, India, is presented, together with detail of clinical observations, method of treatment, and a bacteriological study and analysis in 100 consecutive cases.

A graph is drawn up to show seasonal variation in incidence, and attention drawn to the marked increase in number of cases during the hot season, suggesting sweating as an all important aetiological factor. Cases are classified clinically into oedematous, purulent, granulomatous, membranous and bullous types, the latter being regarded as an unusual form of acute otitis externa, probably geographically limited and seasonal in incidence.

Bacteriological study shows a strikingly high incidence (40 per cent) of *Bacillus pyocyaneus* in pure culture, with streps and staphs present in only 14 per cent in pure culture and 20 per cent in mixed culture with other organisms. A comparative series of bacteriological cultures from the apparently normal meatus is tabulated.

Treatment recommended stresses the great importance of thorough cleaning of the meatus and advocates the empirical use of a penicillin sulphonamide powder as a daily insufflation after thorough cleaning. This is considered to act not only on penicillin sensitive organisms, but to cure by keeping the meatus dry.

# CONGENITAL ABNORMALITIES OF THE PILLARS OF THE FAUCES AND THE ACTION OF THE POSTERIOR PILLARS AND NASOPHARYNGEAL VALVE DURING SPEECH

By MICHAEL C. OLDFIELD (Leeds) and I. P. J. MACNAUGHTAN (Edinburgh)

THE posterior pillars of the fauces play an important role in the production of speech sounds, since their contraction assists in the occlusion of the nasopharyngeal isthmus. Our attention was drawn to this action when examining the movements of the posterior pillars from their postero-inferior aspect through a large pharyngeal fistula in a patient who, some months previously, had attempted to commit suicide by cutting his throat. When he spoke, air escaped through the pharyngeal fistula and the effect on speech was similar to that resulting from the escape of air through the nose when the palate is cleft, as the explosions so necessary for consonant formation could not be produced.

Direct observations were made of the soft palate and pillars of the fauces when certain consonant sounds were attempted. Not only was the soft palate raised but the posterior pillars were seen to contract actively and helped to occlude the nasopharyngeal isthmus. A cinematograph film showing this action was shown at the Royal College of Surgeons during an Arris and Gale lecture on February 12th, 1940 (Oldfield<sup>9</sup>, 1941).

Some patients with congenital abnormalities of the pillars have speech resembling that of the cleft palate patient, the nasopharyngeal valves being incompetent in both conditions.

In 1895, Fullerton<sup>3</sup> described a case in which the left posterior pillar was absent and Gerrie<sup>4</sup> in 1939 described a case in which the left anterior pillar was congenitally absent and closely resembled the one which is described below. In all these cases the tonsil was absent or vestigial on the side of the defect. Newcomb<sup>8</sup> in 1897 reviewed 42 cases of different types of congenital abnormality of the pillars of the fauces and described two new cases of his own. Since that time various authors have described other cases. It would appear from the literature that partial defects are the commonest type of congenital deformity of the pillars; a hiatus is sometimes present in them and only rarely are the pillars completely absent. When a hiatus is present, it usually communicates with the nasopharynx at a point where the pillar unites with the soft palate. The

# Abnormalities of the Pillars of the Fauces

aperture is oval and often symmetrically placed, but unilateral apertures have been reported

## Differential Diagnosis

Chronic ulceration due to congenital or acquired syphilis and accidents associated with tonsillectomy are the commonest causes of severe deformity of the pillars of the fauces. It is important to exclude, if possible, other causes of deformity before a diagnosis of congenital abnormality of the pillars can be made with confidence. The presence of congenital abnormalities in other parts of the body may be considered as contributory evidence of the congenital origin of the faucial defect.

The embryological explanation of these congenital abnormalities is doubtful because the normal process of development of the pillars is still obscure. For instance, Keibel and Mall<sup>6</sup> (1912) stated that the pillars are developed before the second month of intra-uterine life, the anterior pair being formed from the second branchial arches and the posterior pair by the backward prolongation of the palatal elements of the maxillary process towards the lateral wall of the pharynx. Frazer<sup>1</sup> (1940) described the posterior pillars as developing from a wedge-shaped group of cells growing forward into the palatal fold from the third arch. His<sup>5</sup> (1885) on the other hand, believed that the anterior pillars are developed from the second and third arches, which would explain a rare abnormality described by Fridenburg<sup>2</sup> (1908) in which the anterior pillar was double. A small supernumerary anterior pillar was present on each side and formed a rope-like structure running from the lateral margin of the soft palate to the posterior portion of the tongue. It contained muscular tissue and contracted actively when the patient was "gagging". There were also two small apertures which communicated with the pharynx, the tonsil was absent on the right and vestigial on the left. The voice of the patient was said to have a "nasal twang" and "speech resembled cleft palate".

Fridenburg<sup>2</sup> (1908) believed that the abnormality was due to failure of the second and third branchial arches to unite, which, according to His<sup>5</sup> (1885) coalesce early in foetal life to form the anterior pillars.

## 1. Congenital Absence of one Anterior Pillar of the Fauces

### *Case Report*

A R a boy aged 12 years was brought to the Out-patient Department of the General Infirmary at Leeds on May 5th 1939.

The mother stated that one side of the boy's tongue was drawn up at the back and he was unable to pronounce some of his words properly. He was the seventh child and his mother had had no miscarriages. His father, mother, brothers and sisters had no congenital defects. The mother had been told, while in the Maternity Hospital, that "there was something the matter with the inside of his mouth". She noticed also that he did not suckle as well as the

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other six babies had done. He suffered from "acute rheumatism" when he was 11 years old, but there was no history of any serious throat infection.

## *On Examination*

The patient's face and head were asymmetrical, the left side being smaller than the right. On examination of the inside of the mouth, it was noticed that the posterior third of the tongue on the left side was elevated so that it appeared to be continuous with the soft palate (Fig. 1). There was a complete absence of the left anterior pillar of the fauces. The tonsil on the left side was vestigial. The movement of the soft palate was restricted, elevation being prevented by its association with the tongue. The patient's speech was intelligible and, although most other individual sounds could be pronounced, the "T" and "Ch" sounds could not be made at all. He could whistle and blow up toy balloons without any difficulty.

On physical examination there was no evidence of a serious heart lesion or decompensation, but a skiagram of the chest showed a prominence on the convexity of the pulmonary artery shadow such as occurs in congenital pulmonary stenosis. The electrocardiogram showed accentuation of P<sub>2</sub>. An X-ray examination of the skull showed asymmetry of the vault, which appeared to bulge to the right because the left side was poorly developed. There were no physical signs of past or present syphilis and no family history of the disease. The blood Wassermann was negative.

The attachment of the auricle to the head was lower on the left than on the right, and the left ear protruded more than its fellow. There was a left divergent strabismus. The left eye was slightly lower than the right. Vision of the left eye was markedly defective (visual acuity left C.F. at 2 ft. Right 6/6). The right optic disc was normal but the left showed evidence of congenital abnormality and was represented by a funnel-shaped cup. There was an aggregation of pigment round the edges of the cupped area and the blood vessels were arranged in an anomalous manner. The left optic nerve was partially atrophic.

As the patient's general health was in no way affected and he appeared to suffer from no serious disablement apart from the minor defect in speech, it was decided that operative treatment would be meddlesome. Speech training was started and he was discharged from hospital on June 18th, 1939.

## 2. Congenital Abnormality of the Posterior Pillars—Lateral Sphincteric Folds of the Pharynx

### *Case Report*

Gunner A.M., aged 25 years, was referred to us by Captain V. Drosso, R.A.M.C., on May 24th, 1942, complaining of a "sore throat".

Both his parents and his four sisters were stated to be healthy and, as far



FIG. 1

Congenital absence of the left anterior pillar of the fauces. Photograph showing the posterior third of the tongue on the left side elevated and apparently continuous with the soft palate. On the left, the tonsil was vestigial and the anterior pillar of the fauces was absent.



FIG 2

Sketch showing congenital abnormality of the posterior pillars which were represented by lateral sphincteric folds of the pharynx



FIG 3

Anteversion of the Uvula

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as he knew, free from any physical defects. The patient himself had always been a healthy man and had not suffered from any serious illness. He had never had any difficulty in speaking, swallowing or breathing.

### *On Examination*

The patient's oropharynx was seen to be separated from his nasopharynx by a thin diaphragm with an elliptical hiatus in the midline (Fig 2).

The uvula was absent and both tonsils were vestigial. The anterior pillars appeared to be normal. The posterior pillars were pale and thin and arose together from the posterior pharyngeal wall. A little above the common origin, they separated to form two leaf like folds which diverged slightly leaving a median elliptical hiatus, which varied in size according to their tension. These folds joined again before entering the posterior extremity of the soft palate. When the patient gagged, the folds became tense and a well-marked Passavant's ridge could be seen through the upper part of the hiatus (Passavant<sup>10</sup> 1863). In this way complete nasopharyngeal occlusion was effected by the advancement of Passavant's ridge into contact with the posterior surface of the folds and the soft palate.

There was no regurgitation of fluids and the articulation of speech sounds was natural.

Indirect laryngoscopy revealed an abnormally shallow vallecula and a "nibbled" appearance of the free edge of the epiglottis. The larynx was normal. Examination of the nose revealed no abnormality, posterior rhinoscopy was found to be impracticable. A careful general examination showed no evidence of any other congenital abnormality or organic disease. The Wassermann reaction of the blood was negative.

As this patient also suffered no ill effects attributable to the congenital abnormality of the throat, no treatment was necessary.

The formation of the posterior pillars in this patient appears to support the view of Wood Jones<sup>12</sup> (1940) that the pharyngopalatinus represents morphologically two distinct muscles and the usual conception of it, being one muscle with two fasciculi is misleading. Wood Jones<sup>12</sup> believes that only the upper part is the true "palatopharyngeus" and this encircles the nasopharyngeal orifice as a horse-shoe sphincter. These fibres are identical with the fasciculus described by Luschka<sup>7</sup> (1862) and called by Willis<sup>14</sup> (1930) "the palatopharyngeal sphincter", and represent an anatomical entity.

The lower fibres, or palatothyroideus, arise from the posterior margin of the thyroid cartilage and the pharyngeal aponeurosis. In normal subjects, they curve laterally in the side wall of the pharynx before passing medially into the soft palate. When they leave the side wall of the pharynx to approach the palate, they raise folds which we



recognize as the posterior pillars of the fauces. In the case just described, the two muscle elements were even more distinct than normal and formed two separate sphincteric rings throughout most of their course. The upper one formed the normal Passavant's ridge which moved backwards and forwards in a horizontal plane. The lower one formed lateral symmetrical folds which left the posterior wall together, one inch below the ridge of Passavant, and passed directly upwards towards the soft palate, instead of curving laterally round the wall of the pharynx before passing abruptly forward and upward to form the normal posterior pillars. The lateral folds, in the congenital abnormality just described, moved upwards and outwards, opening like curtains in an oblique coronal plane. In either the normal or abnormal arrangements of fibres just described, both muscle elements of the so-called pharyngopalatinus have a cross action; when they contract they form two separate sphincteric rings to assist in the occlusion of the nasopharyngeal valve (Oldfield<sup>9</sup>, 1941).

### 3. Anteversion of the Uvula

#### *Case Report*

Driver D.R., aged 30 years, was admitted to a Maxillo-Facial Unit in the Middle East on February 26th, 1942, suffering from delayed union of a fractured mandible.

When examining the inside of his mouth we found that the uvula was anteverted. It rose in the normal position but instead of passing downwards and backwards, it was curved sharply forward. Its anterior surface was concave and the tip pointed towards the lower central incisors (Fig. 3). On questioning the patient, he stated that he had never had an operation on his throat or tonsils, but he had suffered from tonsillitis about three times a year for as long as he could remember. None of his relations had any obvious congenital deformity, although as might be expected, the patient had not examined their throats very carefully. His sister, however, who spoke quite normally, died from a complication which followed an operation on her throat. The patient's voice and articulation were normal and he complained of no symptoms which might have been related to the abnormality of his uvula. The blood Wassermann was negative.

### Discussion

It appears that the uvula has no mechanical function. Its contribution is not in any way vital to nasopharyngeal occlusion. There was no uvula in the second case and it was completely anteverted in the third, yet nasopharyngeal occlusion was complete and articulation was perfectly natural in both. In the third case the anteversion of the uvula was considered to be congenital in origin, but there was no conclusive evidence, and the history of repeated infections might suggest the possibility of deep cicatricial contracture as the cause of anteversion.

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## Conclusion

Nasopharyngeal occlusion is effected by a complex sphincter mechanism composed of overlapping muscle slings. The posterior wall of the isthmus is drawn forwards to form the ridge of Passavant, by the horse-shoe fibres of the palatopharyngeal sphincter. The lateral walls are drawn inwards by the salpingopharyngeus and the thyropalatinus, (or lower fasciculus of palatopharyngeus). In front, the middle third of the soft palate is raised and drawn back into contact with the postero-superior aspect of the pharyngeal wall; a valve is thus formed which occludes the already narrowed isthmus (Fig. 4).

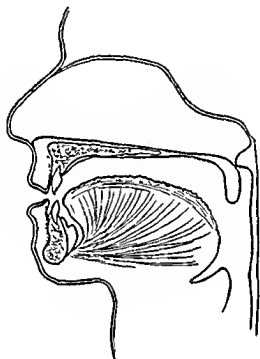


FIG. 4

the soft palate and pharynx The effect on sling is shown When the nasopharyngeal sonant sound, the middle third of the palate is raised to meet the postero-superior pharyngeal wall and comes into contact with Passavant's ridge.

The posterior pillars of the fauces play a subsidiary but important role in speech and assist in the closure of the nasopharyngeal isthmus

In Case 2, owing to a congenital abnormality, the component slings of the sphincter were more widely separated than usual and their actions were easy to see whilst their efficiency was unspoiled

## Summary

1 Types of congenital abnormality of the pillars of the fauces are described.

2. The embryology of the pillars is discussed.

3. Three cases of congenital deformity of the fauces are described :—
  - i. Absence of the left anterior pillar.
  - ii. Lateral pharyngeal sphincteric folds replacing normal posterior pillars.
  - iii. Anteversion of the uvula.
4. The mechanism of the nasopharyngeal sphincter with its overlapping muscle slings is described.
5. The posterior pillars play a subsidiary but important part in nasopharyngeal occlusion and speech production.
6. The uvula has no mechanical function and is not required for nasopharyngeal occlusion.

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# "CONSIDERATIONS REGARDING THE SECONDARY AFTER SENSATIONS CAUSED BY A STIMULATION OF THE SEMICIRCULAR CANAL SYSTEM"\*

SOME REMARKS ON THE PAPER OF L B W JONGKEES  
AND J J GROEN

By ERNEST WODAK (Tel-Aviv, Palestine)

As the authors of the above mentioned paper refer to researches made, many years ago, by M H Fischer and me at the Physiological Institute in Prague†, some remarks about this topic may be allowed me. Jongkees and Groen discuss the alternative phases, each contrary to the other, of the sensations of rotation, furthermore, the exceptional position of the first negative phase as we called it. We held that these phases are of a central origin, whereas Jongkees and Groen believe them to be caused by peripheric changes in the cupula. In their opinion the endeavour to restore the elasticity of the distorted cupula is sufficient to produce the phases of the sensation of rotation and of the after nystagmus, analogous to the optical after images produced by chemical changes in the retina.

(1) The authors are doubtless right in demanding that we must look, first of all, for peripheric changes in the cupula to explain the phenomena of the after-sensations. But, as we duly stressed (*Monatschr f Ohrenheilk*, lviii, 1924), "A peripheric stimulation lasting as long as this with such a periodicity is extremely improbable. Also the analogy to the optical after-images confirms that opinion." At that time, we were of the opinion, backed by A Tschermak and other famous physiologists, that this latter phenomenon is centrally caused. And even to-day, a peripheric origin by chemical changes in the retina, as the authors held it, is not proved beyond any doubt. To support their opinion the authors maintain "that later after-sensations have not always alternating directions, but are sometimes observed in the same direction a few times in succession." In our

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† Besides the paper by M H Fischer and me mentioned by the authors, there are many others in which we during our collaboration from 1919 to 1927, dealt with this topic, as e.g. E Wodak *Mon f Ohrenh* 58 1922. E Wodak and M H Fischer *ibidem*, 58 1924. E Wodak *ibidem* 59 1925. Partly also in my monograph about the past pointing test of Bárány Urban and Schwarzenberg Vienna, 1926. When I stopped my work in the Physiological Institute in 1927, Fischer continued it with other collaborators,

numerous rotation tests we never could see such a course. We did see it by using short rotations (from  $60^\circ$  to  $360^\circ$ ) and could explain this somewhat strange phenomenon as an algebraic sum between the central negative-after-sensation (caused from the original rotation) and the peripheric stimulation in the l. negative phase.

Conceding to the authors that the restitution of the elasticity of the distorted cupula (caused by the flow of the endolymph) does not proceed in a straight undisturbed line, but slowly and with interruptions, we could then, at the utmost, expect a reaction with temporary interruptions, but always going in the same direction, i.e., without the characteristic contrary phases. Therefore, these contrary phases could not be explained on the author's theory.

There is still another phenomenon supporting our opinion for a central origin of the after-sensations, namely our experiences with optical nystagmus and the tonic reflexes caused by the turning wheel (Drehrad\*). The test person fixing the strips of the turning wheel moved horizontally at great speed has the sensation of the rotation of his body in the contrary direction and shows, furthermore, the known optical nystagmus and the body-reflexes. All these phenomena show the same course in phases, one contrary to the other, we observe after the rotation. We can assume that in this type of sensation of rotation there is probably no stimulation of the peripheric labyrinth, and, therefore, we are entitled to maintain that these phases are of a central origin. Although the character of these sensations of rotation is not entirely identical with the sensation after stimulation of the labyrinth, we may, in my opinion, nevertheless compare these phenomena and assume in both of them a central origin of the phases. Also the experiences of sensation of rotation caused by suggestion speaks in the same direction, i.e. for a central origin.

In this assumption of the central origin of these phenomena we are not alone: Abels (*Zeitschr. f. Psychologie*, xliii, 1906, further *Ibid.*, xlv, 1907) explained this phenomenon in conformity with A. Tschermak as centrally caused thus opposing the opinion of J. Breuer (*Ibid.*).

(2) For the l. negative phase we made an exception, assuming here two factors: the centrally caused negative after-image and, besides, a peripheric stimulation of the cupula caused by the flow of the endolymph. If the test person changes the position of his head immediately after stopping the rotation, the person gets a very intensive sensation of rotation, this time in the vertical plane, the direction of which depends on the change of the position of the head. Also this new sensation of vertical rotation shows the characteristic contrary phases, whereby the original sensations of horizontal rotation with their phases remain independently. This test shows us, therefore, two different kinds of sensation of rotation,

\* E. Wodak: *Acta Oto-laryngol.*, xii.

## Considerations regarding Secondary After-Sensations

each with phases the horizontal phases and the vertical ones the first being stronger and longer lasting than the second ones

It seems that Jongkees and Groen overlook this fact of the juxtaposition of the two sensations of rotation, because they are always referring to the vertical sensation which, as a matter of course and also stressed by us is of a peripheric origin Its existence proves in their opinion, the purely peripheric origin of the whole phenomenon in the mentioned test We, however, saw in this test the possibility of separating both active components the centrally caused after images and the peripherically caused sensation of a vertical rotation

*Moreover, clinical experiences of my own seem to support my view* I saw a boy with a cyst of the hypophysis who showed after the rotation test the after-nystagmus with its contrary phases in an excessive and striking manner, not comparable to the faintly visible phases of the after nystagmus in normal persons Because in this case the peripheric vestibular organ was normal this strange phenomenon proves in my opinion or makes it more probable that the phases of the after nystagmus are centrally caused—or at least centrally influenced The same holds true—as I believe—for the phases of the sensation of rotation This and similar cases and their explanation lead me to new views about the vestibular organ itself \*

The authors are right in opposing the assumption of a central origin of some phenomenon as long as all possibilities of its peripheric explanation and origin are not excluded But, I must confess hard as I have tried to find a peripheric explanation for these phenomena I found none and the attempt of Jongkees and Groen to do so does not convince me

\* E Wodak *Acta Otolaryngologica* 11  
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## CLINICAL RECORD

### HÆMORRHAGE FROM THE INTERNAL CAROTID ARTERY FOLLOWING PHARYNGEAL ABSCESES

By E. CARLYLE RICHARDSON (London)

THIS article is written chiefly with a view to amplifying a subject which though rare, has been well written up. By far the greater part of the writings on this subject have come from America. As the general picture of most of these cases conform to a definite pattern, only the new features of a case which came under my observation will be recorded.

A female patient age 5, was admitted to hospital with a retropharyngeal abscess. This was incised in the normal manner and the child subsequently discharged from hospital as cured. A month later she was readmitted to hospital with a history of profuse nasal bleeding. On examination no area from which the bleeding had occurred could be found. The examination of the throat showed some residual swelling but the mucous membrane over this swelling was of definitely healthy appearance. The swelling extended upward into the nasopharynx but did not extend downward. The swelling did not cross the mid-line. As the past history was known and as the swelling was not marked, and as it was covered by normal mucosa, it was considered that the swelling was due to slight residual thickening following the retropharyngeal abscess.

The child was put to bed and kept under observation for some weeks. During this second period in hospital no further bleeding occurred. The child was discharged and sent home. She was readmitted again in two months from the first date with a history of another nasal hæmorrhage. The hæmorrhage *had come on suddenly and was profuse*. On admission to hospital, bleeding had stopped but the child was pale though her general condition was good. She was again put to bed and observed. No bleeding area could be found. A few days after admission the child had another sudden hæmorrhage and died before the doctor could get to her. A post-mortem examination revealed erosion of the internal carotid artery.

The interesting feature of this case was the great lapse of time. Two months between the initial retropharyngeal abscess and the final fatal hæmorrhage. As far as I have been able to ascertain, there is no instance in any of the other reported cases of such a long lapse of time between factual diagnosis of an abscess and the final fatal hæmorrhage or for that matter the first hæmorrhage. Havens (*Amer. J. Dis. Child.*, lviii) reported a case of a child, girl, age 6 who had been "ailing" for two months; when he saw the child, bleeding had occurred 24 hours previously. It is fair to assume that this child had not had a retropharyngeal abscess for two months. This case also died and a post-mortem showed erosion of the carotid, high up on the post-pharyngeal wall.

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The main features of this symptom complex are the patients are usually children between the ages of 2 and 10. Most common around 5, although Insley reported a case in a patient 26 years old. The condition is most commonly preceded by a head cold, but it might also follow an attack of tonsillitis. There is very often present a cervical adenitis and there may or may not be some cervical swelling. Dysphagia is not infrequently present. Bleeding may occur before the patient is seen or may occur after surgical intervention. There is nothing to suggest that surgical intervention might cause the condition, although Lifshutz in analysing 21 cases showed that 12 cases occurred after incision. In by far the majority of cases, there is an initial warning hæmorrhage. There is always present in these cases a retropharyngeal abscess. It is right to point out here, that the Americans who have reported by far the greater number of cases, speak of a retropharyngeal abscess, a parapharyngeal abscess and a peritonsillar abscess. There seem to be definite anatomical and pathological grounds for this classification. A few of the rarer features reported include Horner's syndrome (Insley, *J Laryng and Otol* October 16th, 1944) bleeding from the auditory meatus (Richards, *Ann. Otol. Laryng.* i., 1221). As a general rule no area of hæmorrhage or ulceration can be made out even after two or three attacks of hæmorrhage. Clinical examination generally only reveals the abscess which may or may not have been incised before bleeding has occurred. Sometimes when bleeding occurs into the tissues, a plum coloured mucosa is diagnostic.

## Diagnostic Points are :

(a) Spontaneous hæmorrhage which is so severe as to suggest that the bleeding has not occurred from a minor vessel.

(b) Where the swelling does not completely subside after incision.

(c) The presence of a hæmatoma as evidenced by a tense brawny and plum coloured mucosa.

Hæmorrhage following Parapharyngeal Abscess	No. of cases	Ligation of Ext Carotid.		Ligation of Common Carotid		No Ligation	
		Lived	Died	Lived	Died	Lived.	Died.
(1) Peritonsillar abscess	85	8	3	15	2	29	29
(2) Peritonsillar and Parapharyngeal abscess	31	3	1	5	1	4	17
(3) Retropharyngeal abscess	32	0	2	2	3	1	24
(4) Retropharyngeal and Parapharyngeal abscess	28	0	1	8	6	0	13
(5) Parapharyngeal	21	1	0	3	4	1	12
(6) Cervical cellulitis	30	0	0	2	3	1	24
	227	12	7	35	19	36	119



## E. Carlyle Richardson

(d) Increasing pain in the neck with local swelling and trismus especially after incision.

(e) Presence of pulsation.

If any one of these signs are present in a case of bleeding from the nose or throat in a case of pharyngeal abscess, erosion of one of the carotids should be suspected.

The treatment of these cases is undoubtedly surgical, for more cases would end in death. The chart on the previous page is taken from Salinger and Pearlman, who collected over 227 cases.

This shows most conclusively that the scales are heavily balanced against a patient who is denied operative interference. The chart becomes more impressive if put in the following way.

	Lived.	Died.
Treated by Surgery .....	47	26
Not treated by Surgery .....	36	119

Before the question of which artery should be tied the following chart (Salinger and Pearlman) should be studied. It is a post-mortem analysis of those cases on which post-mortems were done.

	Erosion of Int. Carotid.	Erosion of Ext. Carotid.	Other arteries.	Common Carotid.	Int. Jugular.	False aneurysm and erosion of Internal Carotid.
Peritonsillar abscess	7	0	4	0	0	4
Peritonsillar and Parapharyngeal abscess	5	3	3	3	0	2
Retropharyngeal abscess	11	0	5	2	0	3
Retropharyngeal and Parapharyngeal abscess	1	0	0	2	0	7
Parapharyngeal abscess	5	1	2	1	1	3
Cervical	1	0	0	1	13	0
	30	4	14	9	14	19

Thus in 90 post-mortem cases the internal carotid was involved in 49 cases. The external carotid in 4 cases. Other arteries in 14. The common carotid in 9.

It should be pointed out here that the post-mortem analysis showed that the main cause for jugular hæmorrhage was cervical cellulitis following scarlet fever.

Thus it would appear that in most of these cases it would be advisable to tie the internal carotid or if the abscess is relatively low in the pharynx the common carotid should be tied. The end result of operation in these cases is complete subsiding of symptoms with no residual hæmiplegia. In one case reported by Pearlman a contralateral facial palsy and hæmiplegia which was present before operation was cured by ligation of the common carotid. It is possible that the age of these patients prevent the appearance of untoward

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results that might occur in adults In a few of the reported cases, multiple ligations were carried out Pearlman ligated the common carotid twice in one case Richards ligated first the common carotid, but subsequently ligated the internal and the external carotid on the same case because of the reappearance of bleeding Both of these cases completely recovered The reason as to why the internal carotid is so very often involved is probably due to the local anatomy of the parapharyngeal and retropharyngeal spaces and to the fact that the internal carotid lies normally closer to the pharyngeal wall than the external carotid The internal carotid is often the site of aneurysmal dilatation and follows a tortuous course Schaffer, *J Amer med Ass*, 1921, described a case of fatal hæmorrhage during tonsillectomy due to an aberrant internal carotid artery He claimed to know of three others Carmack in 1929 reported five deaths which were presumably due to the same cause Thus the position of this vessel, its tendency to tortuosity and aneurysmal dilatations renders it more liable to be affected

The unsolved question is whether infection is blood borne or lymphatic Since most cases of cellulitis following scarlet fever end as hæmorrhage from internal jugular and as a blood borne infection (thrombophlebitis) is most likely to cause a jugular complication, it is probable that the main cause is a lymphangitis which causes an adenitis of the glands lying along the carotid sheath It should be pointed out that the highest of these glands belong to the retropharyngeal group of lymph glands whereas the parapharyngeal space is occupied by glands found more in relation to the external and common carotid It is possible that in these cases signs of carotid sheath involvement may be made manifest by pulse irregularity from vagal involvement and in the exceptional case of Horner's syndrome

## Conclusion

- (1) In cases of hæmorrhage following pharyngeal abscess the internal carotid is most often involved
- (2) The signs and symptoms are discussed
- (3) The question as to the pathology is raised

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## FURTHER OBSERVATIONS ON TEMPORARY DEAFNESS FOLLOWING EXPOSURE TO GUNFIRE

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### 1. Summary

Subjects were exposed to blast from the firing of blank charges from a .303 rifle in the laboratory

The results of these experiments together with those previously reported (1946) are discussed in relation to the following problems

- (a) Development of deafness with successive rounds
- (b) Variation in sensitivity in different subjects
- (c) Changes in sensitivity in one and the same subject
- (d) Effect of different rates of fire
- (e) Shape of the audiogram
- (f) Recovery curves
- (g) Onset of permanent deafness

### 2. Introduction

The work reported here is a continuation of that described in an earlier paper on the subject of deafness due to gunblast (Murray and Reid, 1946) The present paper deals with the results of experiments in the laboratory in which blast was produced by firing blank charges from a rifle and a consideration of certain aspects of these results and those reported in the previous paper, in greater detail

### 3. Laboratory Experiments

Blast was produced in the laboratory by firing blank charges from a .303 rifle mounted in a vice. Twelve subjects of which only two (subjects G.R. and E.P.S.), had also been used in the survey reported in the last paper, were the experimental subjects in this series. Eight of the remaining ten were fourth-year medical students in the University of Sydney, and the other two were laboratory assistants.

After a number of preliminary experiments with subject E.P.S., it was decided to expose the right ear of each subject at what is hereinafter called position A. In this position, the subject sat facing forwards in front of, and to the left of the rifle, with the tragus of the right ear nine inches to the left and three inches in front of the muzzle. This position enabled a reasonable degree of deafness to be produced with the firing of comparatively few rounds (about ten) in most of the subjects, and caused little or no effect when one or two rounds only, were fired.

Other positions (referred to in the appendix) were used occasionally. In position B. the tragus was nine inches to the left of and  $1\frac{1}{2}$  inches in front of the muzzle; in position D it was eight inches to the left of and four inches in front of the muzzle.

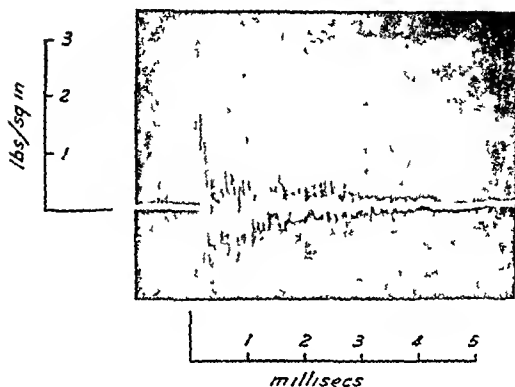
These experiments made possible the comparison of the effects of similar exposures in different subjects, the variation in effect in the same subject when similar exposures were repeated, the effect of various rates of fire, and the development of deafness in relation to the number of rounds fired.

*Observations:* These consisted of an examination of the eardrums, a Rinne test and an audiometric examination before and after firing. Details are similar to those described in the previous paper. Where the term "average hearing loss" is used it represents the average loss of hearing over a band of four octaves from 512 to 8192 c.p.s.

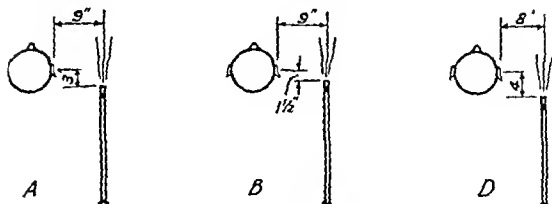
### 4. Results

The blast pressure curve at position A, determined by means of a Piezo Gauge, and a cathode ray oscillograph, is illustrated in Fig. 1. Compared with the blast wave photographs in Report No. 7, showing the blast waves from large guns it can be seen that in a given time there are a greater number of positive and negative pressure peaks, the wave shape resembling more closely that produced by the mortars. The peak pressure is of the order of 3-4 pounds to the square inch at position A. There was variation from one shot to another, but with exposures of ten or more rounds variation from one multiple exposure to another was very small.

The hearing losses of the subjects exposed to blast in the laboratory



*TYPICAL BLAST PRESSURE WAVE*



*RIFLE POSITIONS*

Blast Pressures and Positions used in Experiment Blank Rounds from Lee Enfield Rifle

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# Temporary Deafness following Exposure to Gunfire

are set out in Table 2 in the appendix. Unless otherwise indicated these measurements were made 10-15 minutes after exposure.

In the presentation of these results it is proposed to discuss them together with some of those in the preceding paper under the following headings:

- (a) Development of deafness with successive rounds
- (b) Variation in sensitivity in different subjects
- (c) Changes in sensitivity in one and the same subject
- (d) Effect of varying the rate of fire
- (e) Frequencies involved
- (f) Recovery curves
- (g) Onset of permanent deafness

## DISCUSSION OF RESULTS

### 5 Development of Deafness with Successive Rounds

The statement is frequently made by deafened gunners and has been stated in the literature (Passe, 1940), that the number of rounds does not seem to matter. Rather, it is a single shot of unexpected severity or one which catches the subject unawares, which causes the deafness during a shoot.

These experiments, however, make it clear that a round or a group of rounds either of which causes little or no damage to the subject in question, may cause a cumulative effect when repeated at suitable intervals.

Because each exposure to a single shot in a series was uncontrollably variable, in some of the experiments the blast produced by each shot was measured in a corresponding position on the other side of the gun so that anomalies (if any) in the results, might possibly be interpreted in terms of variation in the blast pressure to which the subject was exposed. However, as Fig. 2 indicates, the average hearing loss for each subject usually steadily increased (with slight fluctuations) as each round was fired until, with some subjects, further shots at the same intervals caused only slight further increases in deafness.

In the experiments used for making Fig. 2 the subjects were exposed in position A, shots being fired at fifteen minute intervals and the audiometric tests done between ten and fifteen minutes after each shot.

Similar results to these were obtained when audiograms were taken after each group of ten rounds in a series of fifty rounds to which R J J was exposed, and for G R, when single rounds were separated by five-minute intervals.

When we consider the development of deafness in terms of the individual frequencies involved it is found that sometimes the first effects



are recorded mainly at 9749 c.p.s., sometimes at 4096 or 5793 c.p.s. and sometimes in both these regions. As the number of rounds increased, the effect in these regions spread to involve frequencies above and below those initially affected. Not uncommonly, therefore, there was a lag of several

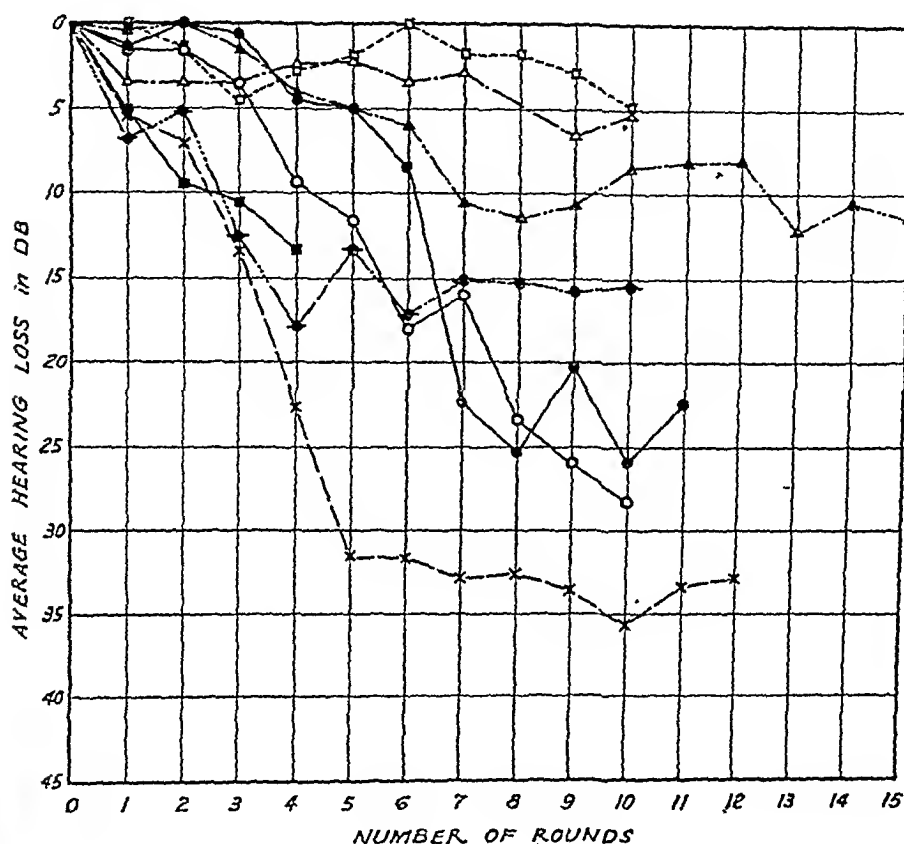


FIG. 2.

Graph illustrating the effect of number of rounds fired on the average hearing loss (from 512 to 8192 C.P.S.) for 8 different ears in 8 experiments, firing at 15 minute intervals, position A, see text.

shots before hearing loss became detectable in several frequencies. Fig. 3A shows this. This subject showed his initial loss at 9747 and not until four shots had been fired did the loss at 8192 c.p.s. exceed 5 db. Deafness (20 db) was not detected at 512 until after the seventh shot.

# Temporary Deafness following Exposure to Gunfire

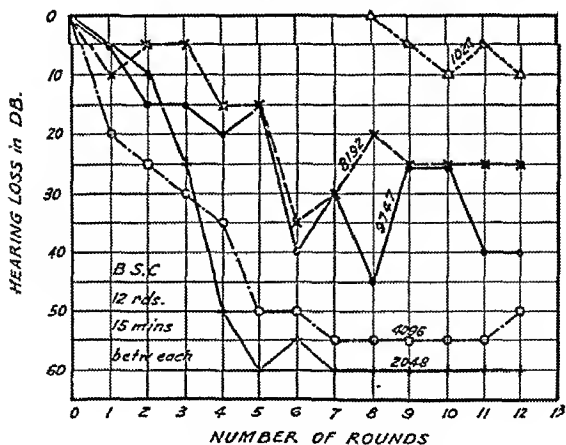
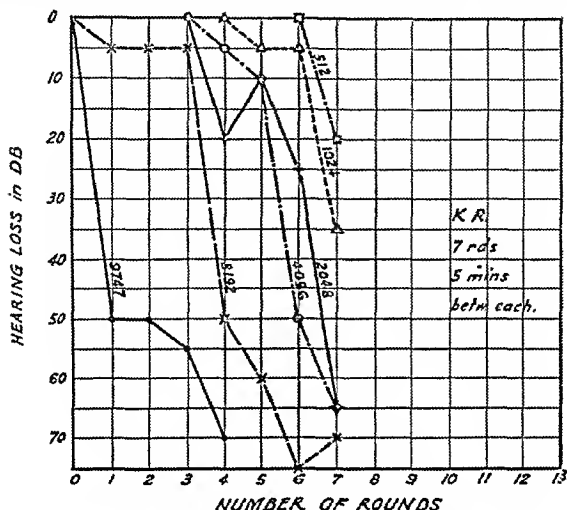


FIG 3A AND 3B

Graphs showing development of deafness at individual frequencies with successive shots for two subjects

The audiogram of this subject is shown in Fig. 7*e*. It is interesting to note that after the period of lag, hearing in the various frequencies fell away very rapidly. Fig. 3*b* illustrates another manner in which deafness may develop with respect to the various frequencies. This subject showed the greatest initial loss at 4096 c.p.s., but all frequencies from 9747 to 2048 were affected. As the number of rounds increased deafness increased both above and below the 4096 level and actually slightly more hearing loss was produced at 2048 than at 4096 c.p.s. The frequency of 1024 was not affected until nine shots had been fired. It is interesting to note, also, that after five or six rounds had been fired there was little or no further change in the peak loss which remained at about 60 db. The final audiogram of this subject after the twelve rounds is shown in Fig. 7*c*.

## 6. Variation in Sensitivity in Different Subjects

It was apparent in the field survey and it has frequently been stated by gunners that there is a considerable range in the sensitivity to gunblast from one subject to another. A statement commonly made was expressed in words like this ; " I never or seldom wear ear plugs because the blast never seems to worry me." While many who made this kind of statement did prove on examination to have been deafened, there were several who, to judge from their history had been equally exposed as had their deaf fellows, gave audiograms within normal limits.

The variation in sensitivity is much more clearly shown in the laboratory experiments where it was possible to control the exposure of each subject. Fig. 2 already referred to, illustrates this variation. In addition to the subjects whose records have been used in making this figure, there were others who were extraordinarily insensitive. For example, R.A.W., K.B., and R.J.J. (see Table 2), were scarcely affected by ten shots at ten-second intervals—each exposure being the first one for each man. P.W. was unaffected by a similar exposure, his fourth. Subject R.J.J. was unaffected by fifty rounds in groups of ten at five-second intervals with five-minute intervals between each group ; and J.A. was hardly affected by fifty rounds at ten-second intervals. These were the fifth and sixth exposures respectively for each of the subjects. The reason for indicating the number of previous exposures will appear later (section 7).

There was no evidence that the shape or size of the external auditory canal, or the position of the pinna relative to the head were important factors in causing the variation in sensitivity from one subject to another. A possible factor so far as gunners in the field are concerned, is the presence or absence of a plug of wax. The first experiment with J.A. recorded in Table 2 was made with his ear firmly plugged with wax. In the second

# Temporary Deafness following Exposure to Gunfire

experiment this was removed and there was an increase in susceptibility but the plug could not have been responsible for the slight sensitivity which continued to be shown by this subject

Because of such variation in sensitivity, it has been suggested (e.g. Wilson 1942 1944) that after preliminary testing, by exposure to pure tones or to noise susceptible subjects should be excluded from gunnery or occupations likely to damage hearing. This would be very desirable as a long-range policy, particularly in industry where long continued exposure to noise is likely and when inefficient means of protection such as cotton wool is worn. However the immediate practical solution is to provide men with efficient plugs and to ensure that they are worn. Even if susceptible subjects were excluded, adequate ear protection would be still essential for those accepted.

The variation in the attitude of artillery personnel to gunfire deafness may be mentioned here, because it is readily understandable that if a man is of a degree of sensitivity comparable with that represented by one of the upper curves of Fig. 2, he naturally will be inclined to the view that guns have little effect upon hearing and that those who complain make much ado about very little. On the other hand, men who have been made deaf display usually great interest in measures for the prevention of gunfire deafness.

TABLE I  
AVERAGE HEARING LOSSES FOR VARIOUS EXPOSURES

Subject	Details		Db Loss (Exposure in chronological order)				
			1	2	3	4	5
B S C	10 rds	15 interval	33.5	—	—	—	10.3
	10 rds	5 interval	—	—	14.2	—	—
	10 rds	10" interval	—	26.7	—	17.4	—
C W	10 rds	10" interval	36.9	—	24.5	—	—
	10 rds	15 interval	—	28.6	—	—	—
P W	10 rds	15 interval	15.3	—	5.5	—	—
	10 rds	10" interval	—	11.9	—	0.5	5.0
C L I	10 rds	10" interval	13.8	—	3.1	—	—
	10 rds	15" interval	—	4.8	—	—	—
K R	7 rds	5 interval	52.0	1" 0	9.4	—	—
R J J	10 rds	10" interval	1.0	—	—	—	—
	50 rds	in groups of 10—	—	—	—	—	—
	5 between each	5" between each	—	36.5	16.5	—	13.0
H C B	11 rds	15 interval	24.8	—	—	—	—
	11 rds	10" interval	—	26.5	27.7	—	—

## 7. Variation in Sensitivity in one and the Same Subject

A contributing factor to the variation in sensitivity among different subjects, is the fact that the hearing loss of a given individual may depend on his previous history of exposure to blast. Compare the two

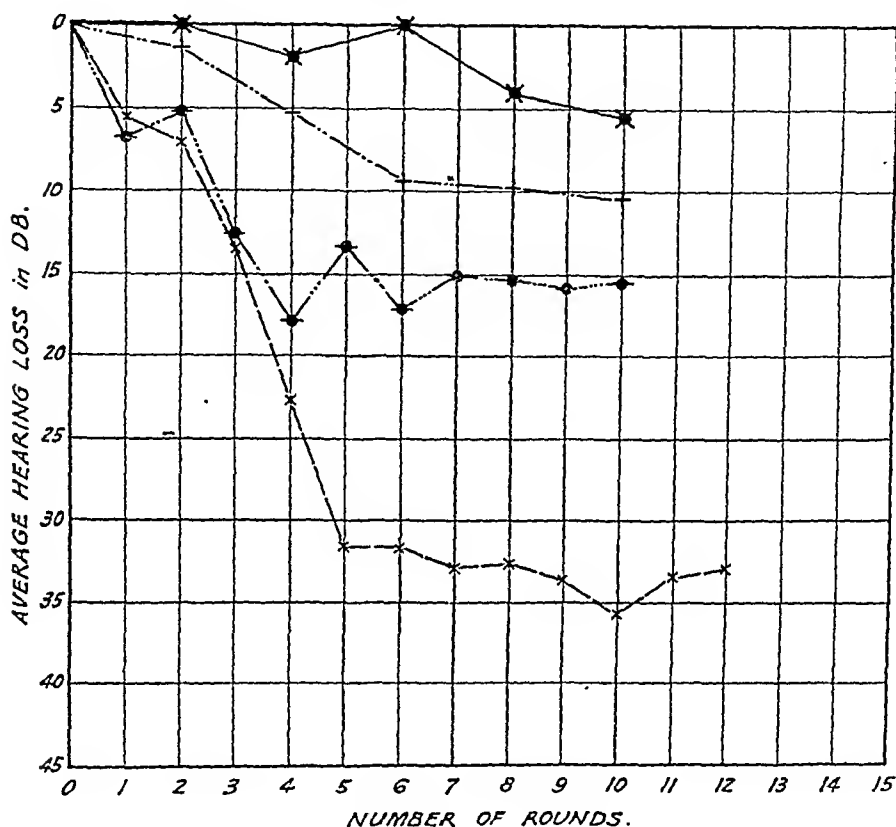


FIG. 4.  
 B.S.C. Right Ear 6-9-44 x—x  
 B.S.C. " " 3-10-44 +—+  
 P.W. " " 18-9-44 ●—●  
 P.W. " " 2-10-44 x—x

Graph illustrating the effect of number of rounds fired on the average hearing loss (from 512 to 8192 c.p.s.) for 2 different ears, each at 2 different times, firing at 15-minute intervals, position (A), see text.

curves for each of the subjects B.S.C. and P.W. in Fig. 4, the series of curves in Fig. 5, and the data in Table 1. In Table 1 are set out the hearing losses sustained by a number of subjects showing the average hearing losses produced in relation to the chronological order of exposure.

# Temporary Deafness following Exposure to Gunfire

There was, as pointed out already, variation in the blast pressure from one round to another, but when the effect of groups of several rounds is being compared on different occasions, the variation in the exposure becomes quite small. Variation in the response of the individual when the same exposures were repeated is to be expected. Nevertheless, for any particular kind of exposure only one subject (H C B see Table 1) exhibited as great a degree of hearing loss on subsequent exposure as on the first occasion. There was, for this subject, an interval of about five months between each exposure. All other subjects showed less hearing loss on subsequent exposure to the same set of conditions.

This decrease in sensitivity affected mainly the lower frequencies of those involved (usually 1024 and 2048 c p s) but higher frequencies also became resistant. Generally this decrease in sensitivity was most marked between the first two although usually continued with subsequent exposures in a series. These facts are illustrated by examining the series of figures in Table 1 for the subjects B S C, P W, R J J, C L F, C W, and K R. Fig 5 shows the audiograms of the first three of these subjects. In this illustration the losses are represented relative to the audiometer zero, by so doing it is made clear that the decrease in hearing loss is not merely an expression of a rise in the pre-exposure threshold (i.e. residual deafness).

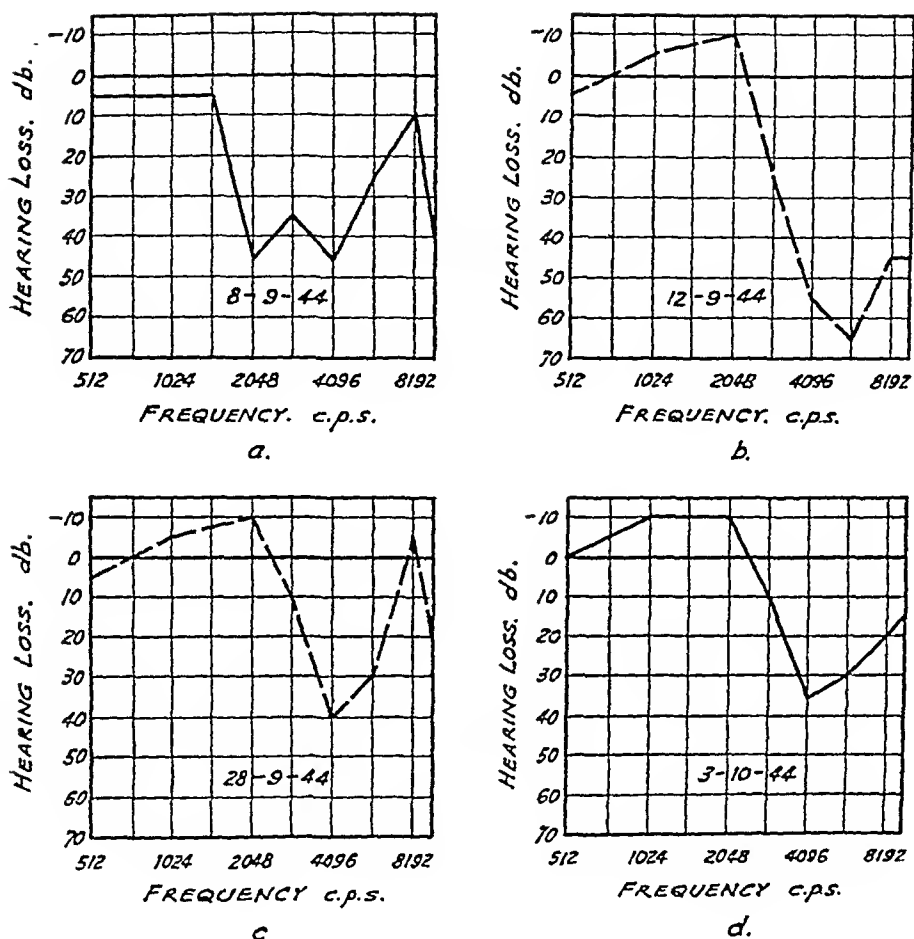
The nature of this alteration in susceptibility is unknown. It may be due, on the one hand, to the extent to which subjects can, in anticipation of the blast, learn to voluntarily contract their intra-aural muscles, or on the other hand it may be due to a "toughening" of the basilar membrane associated possibly with an increase in the intercellular substance (Compare the development of thick skin on the soles of the feet). Time and the availability of subjects did not permit further experiments, a clue as to its nature may have been obtained by determining whether the repeated exposure of one ear resulted in decreased susceptibility of the other. If this were so, it would exclude the second of the alternatives suggested above.

Whatever may be the explanation it may also be the basis of the variation in susceptibility between different subjects, described in the previous section. This basis need not, of course, have been produced by previous exposure, but may represent the person to person variation in the structure and function of the ear. For example, at least two subjects, R A W and K B who were very insensitive the first time they were exposed, gave no indication of previous trauma or experience with guns, likely to have produced this insensitivity.

## 8. Effect of Varying the Rate of Fire

### (a) VERY RAPID RATES

When the observations reported in the previous paper were made



Subject B.S.C.

10 Rounds on dates shown

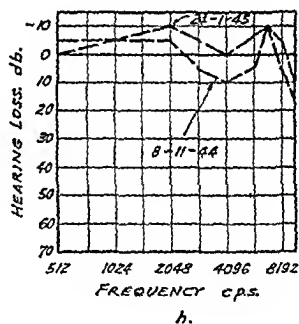
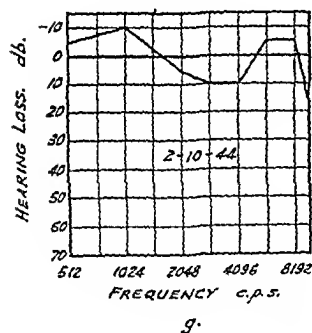
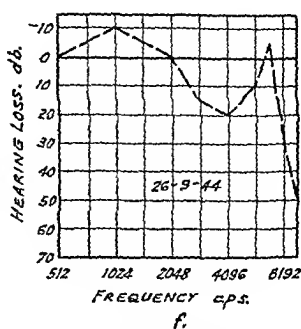
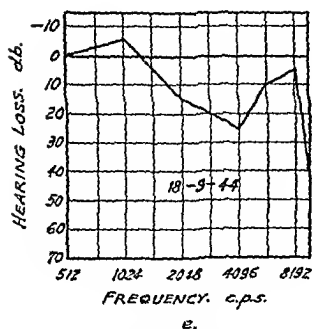
Intervals :- 15 minutes ———

10 seconds - - - - -

FIG. 5.

Effect of exposure at different rates of fire to same person at different times.

# Temporary Deafness following Exposure to Gunfire



Subject P.W.

10 Rounds on dates shown.

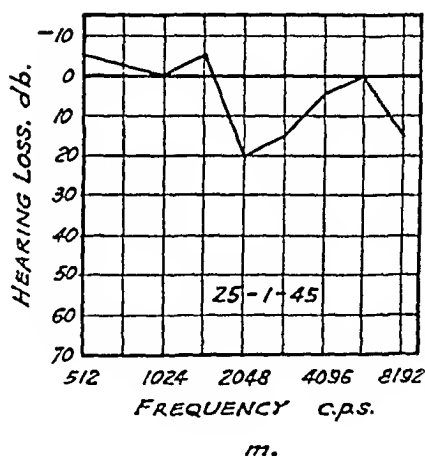
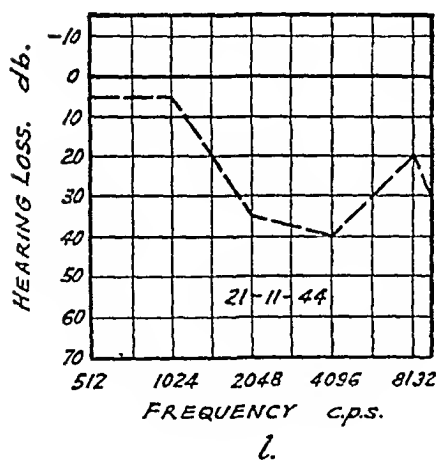
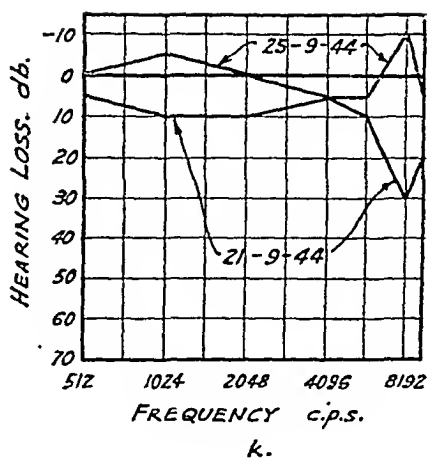
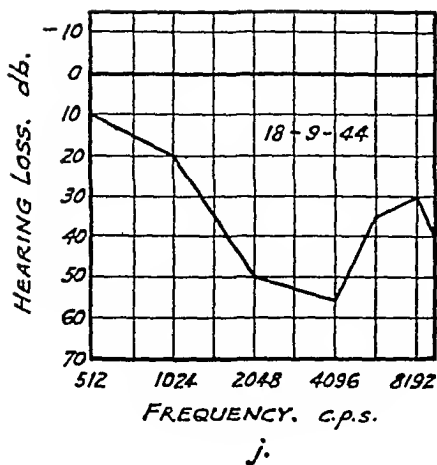
Intervals :- 15 minutes ————

10 seconds ————

FIG 5

Effect of exposure at different rates of fire to same person at different times





Subject R.J.J.

50 Rounds on dates shown

In groups of 10 at 5 second intervals between shots

Intervals between groups :- 5 minutes ———

5 seconds ———

FIG 5.

Effect of exposure at different rates of fire to same person at different times

# Temporary Deafness following Exposure to Gunfire

on the effect on hearing of the firing of small arms, the impression was formed that the rifle was in causing deafness, more effective than the machine gun

Because of this, four subjects were exposed to twenty eight rounds from a Bren gun on two occasions, on the first the rate of fire being approximately 500 per minute and on the second shots were fired every ten to twenty seconds. One subject, was insensitive to either rate, but with the other three, the slower rate was much more effective in causing loss of hearing than when the twenty eight rounds were fired in a single burst. These observations are shown in Fig 6

A possible explanation of this result is as follows. the period from the onset of a sound to the maximal response of the intra aural reflex is about thirty milliseconds. The duration of the blast impulse from a single shot is less than this (see Fig 1). This means that the ear is unprotected by the reflex when one shot is fired and when shots are repeated at sufficiently long intervals, each shot causes an impulse which reaches an unprotected ear. On the other hand with very rapid rates of fire as obtained with a burst from a machine gun the first impulse sets off the intra aural reflex which gives some protection from those which rapidly follow. We do not know how long the intra aural muscles may remain contracted following exposure to blast pressure of this order. Contraction probably lasts as long as the interval between the rapidly fired shots (i.e., 120 msec)

In contrast to these results Davis *et al* (OSRD 889) who expected that repeated interruption of a given amount of a pure tone might render it more effective in producing hearing loss, obtained results contrary to this expectation. They found that interruption of a given amount of sound at 140 db (at rates from one in ten seconds to four per second) so as to spread it over double the total time slightly reduces or else does not materially alter its effectiveness in producing hearing loss. Sometimes evidence of labyrinthine stimulation was greater with the interrupted tone.

It is possible that an increase in hearing loss due to interruptions lasting a few seconds appears only when the total time of stimulation is very short and the pressure variation at the ear is of the order of a few pounds per square inch, such as occurs with gunblast and does not appear when the duration of the sound is of the order of a few minutes and the pressure variation is that which would be represented by 140 db

## (b) MODERATELY RAPID AND SLOW RATES

Since a number of rounds is more effective in causing a loss of hearing than a single one, it is to be expected that if the interval between rounds is sufficiently enlarged the effect should be minimal, and equivalent to the effect of one round. This is, in fact, similar to what happens when in the course of these experiments exposures are repeated at intervals of

## EFFECT OF RATE OF FIRE.

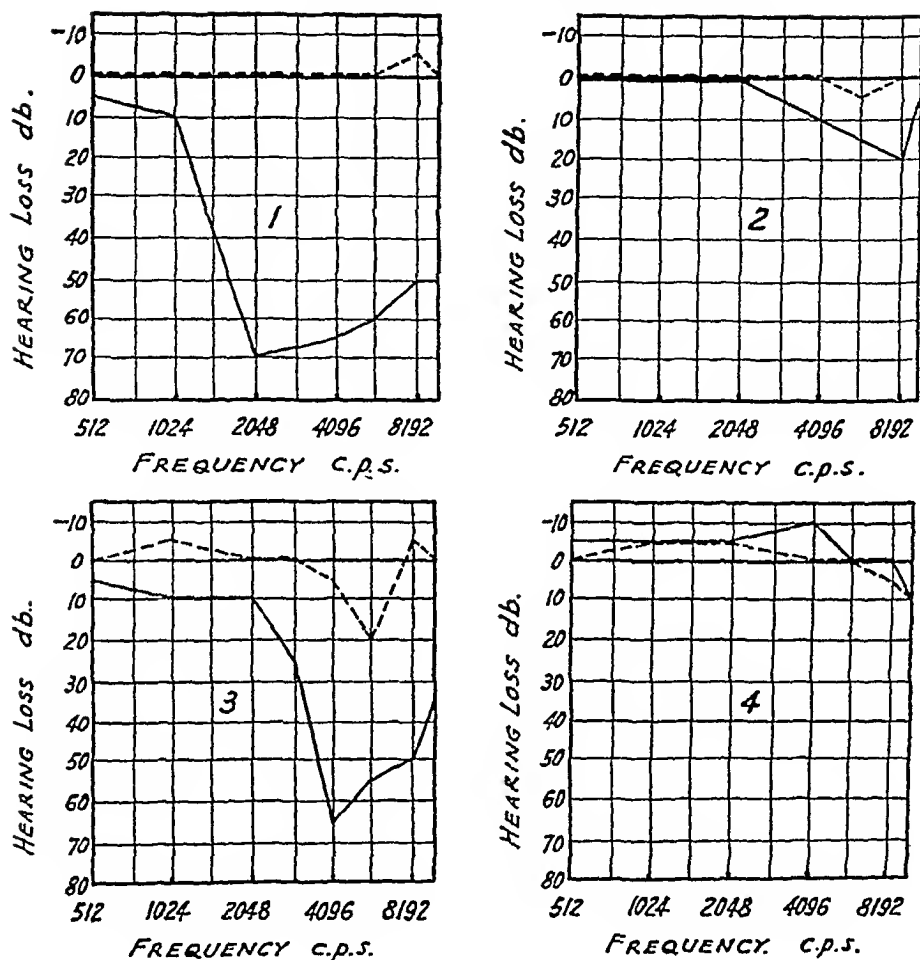


FIG. 6.

Graphs illustrating the difference in the deafness produced after exposure to 28 rounds of Bren .303 fired rapidly (approximately 500/min.) and after exposure to 28 rounds fired at intervals of from 10 to 20 seconds. The former is shown by broken lines, and the latter by full lines respectively. For figures 1, 2 and 3 the test was made 10 to 20 minutes after completion of exposure, and for figure 4, 2 to 7 minutes after.

1. Subject D. G. Left ear.
2. Subject G. R. Left ear.
3. Subject Miss A.M.L. Right ear.
4. Subject J.M. Right ear.

Pre-exposure thresholds are represented by the horizontal full lines through 0 db.

# Temporary Deafness following Exposure to Gunfire

one or several days. It would be expected also, that as the interval between rounds decreases from its value at this minimal level, the effect on hearing should increase as the time of firing of each round encroaches more and more into the period of recovery from the one preceding it.

With this in mind, observations were made to compare the effect of trauma repeated at intervals of 5-15 minutes with that of similar trauma repeated at 5-10 second intervals.

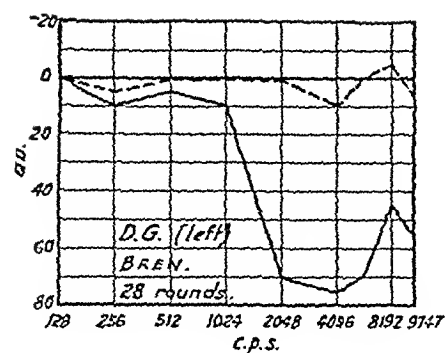
The results of the experiments are set out in Table 1 and some of them are illustrated in Fig. 5. Generally speaking, for the frequencies of 4096 and above, the more rapid rate produced a greater degree of deafness than did the slower rate. For frequencies below this, decrease in sensitivity made the interpretation of the results difficult. For example, the unexpected impression was obtained that, compared with the rapid rate, the slow rate of fire produced its main effect in the frequency range 2048-4096 c p s, producing a notched type of audiogram. On further experimentation it was realized that this had been the case only when the slower rate was presented first and on continuing to present the two sorts of exposure alternatively this kind of difference disappeared. Unfortunately some of the subjects in whom it was intended to reverse the order proved rather insensitive.

It was shown (Sect. 5) that many subjects in the development of deafness with successive rounds, develop at some stage a notched audiogram. It is not unreasonable to consider that as the rate of stimulation is increased then frequencies, which are less vulnerable and which ordinarily recover in the intervals between stimuli, become more noticeably affected. It will also be shown later that the lower frequencies recover much more rapidly than the higher so that with slower rates of fire one would not have expected the main effect to extend to 2048 rather than to 8192 c p s. On the other hand it is the lower frequencies which show most markedly a decrease in susceptibility with subsequent exposures.

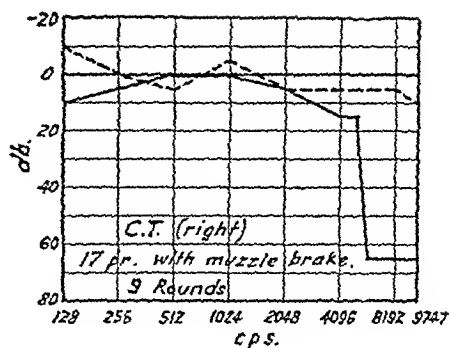
In view of these facts the notching produced by the slower rate of fire extending in some subjects to involve lower frequencies more markedly than occurred with the rapid rate, must be regarded as fortuitous. When one takes into consideration decrease in susceptibility, it can be stated that a greater effect is produced with a more rapid rate of fire (unless that rate is so rapid that the ear is protected from the succession of stimuli by the intra aural reflex).

## 9. Frequencies Involved

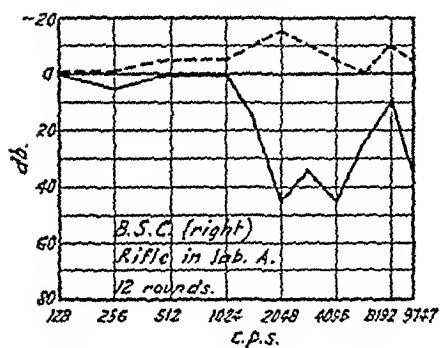
All types of gunfire affect predominantly the higher frequencies. There is no consistent difference between the shape of the audiogram after exposure to the guns which produce a "boom" and after exposure to the guns which produce a sharp 'crack'. The difference in the shapes



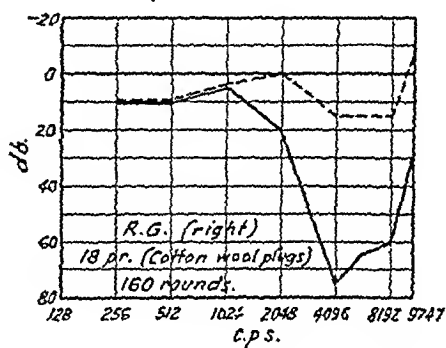
a.



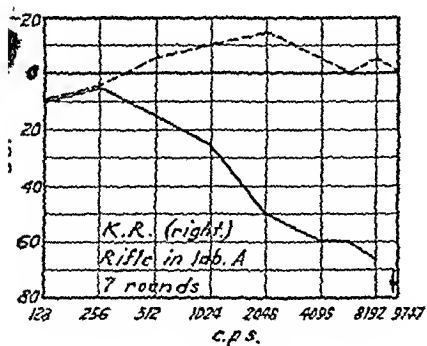
b.



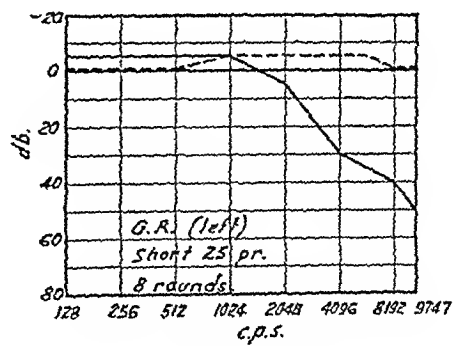
c.



d.



e.



f.

BEFORE EXPOSURE ----- AFTER EXPOSURE —————

FIG. 7.

Audiograms of subjects showing temporary deafness after exposure to gunfire.

# Temporary Deafness following Exposure to Gunfire

which were observed depend on the individual rather than on the gun. Each subject tended to reproduce the same general shape of audiogram when exposures were repeated, although there were some exceptions to this rule.

Most of the shapes which may be met with are illustrated in Fig. 7, but reference may be made to any of the other figures in this or the previous paper when the next paragraph is read. In Fig. 7 the losses are represented relative to the audiometer threshold, this has been done in order to facilitate comparison with the audiograms in Fig. 8, of men suffering from permanent deafness.

Usually there is a loss beginning at 512, 1024, 2048, or higher c.p.s., and extending with progressively increasing loss into the higher frequencies as in Figs 7e and 7f. The loss of hearing may increase rapidly to about its maximum over one octave as in 7a, sometimes it begins very abruptly indeed as in Fig 7b. Quite commonly this increase in threshold, progressing as the frequency increases, is interrupted at about the region of 8192 c.p.s. where it is slightly lower than at say, 4096 c.p.s. When this interruption is more pronounced distinct notching is produced which may be wide or narrow with the maximum loss at 2048, 4096 or 5793 but most commonly about 4096 c.p.s. Here the frequencies above the "notch" are unaffected or only slightly so, still higher, at 9747 c.p.s., it is quite common to have a further falling away (see Fig 7c and other figures in this and the previous paper).

It is interesting to note that all the forms of audiograms met with in the experiments on temporary deafness were represented in a survey of artillery personnel, for the incidence of permanent deafness. This is illustrated by Figs 7 and 8. In the preparation of the figures, audiograms of subjects reported in the previous paper have been chosen in order to represent, as far as possible, the various types of audiograms.

In the figures of other workers who exposed subjects to noise, sometimes there is notching of the audiograms and sometimes there is a continuous loss in the upper frequencies. It appears that there is no shape of audiogram which can be regarded as characteristic of the effects of gunblast as distinct from the effects of noise or the effects of senility.

It is probable that the curve in Fig. 7a represents a more severe form of the condition expressed by the curve in Fig. 7c. Nevertheless the differences in the shape of audiograms in general cannot be interpreted simply in terms of the severity of the exposure, individual differences play a big part. Where it was possible to watch the development of deafness by taking audiograms after each round or group in was seen with increasing deafness there was a spread into the lower frequencies from the regions initially affected, resulting in one or other of the types of curve seen in Figs. 7a, 7b, 7d.

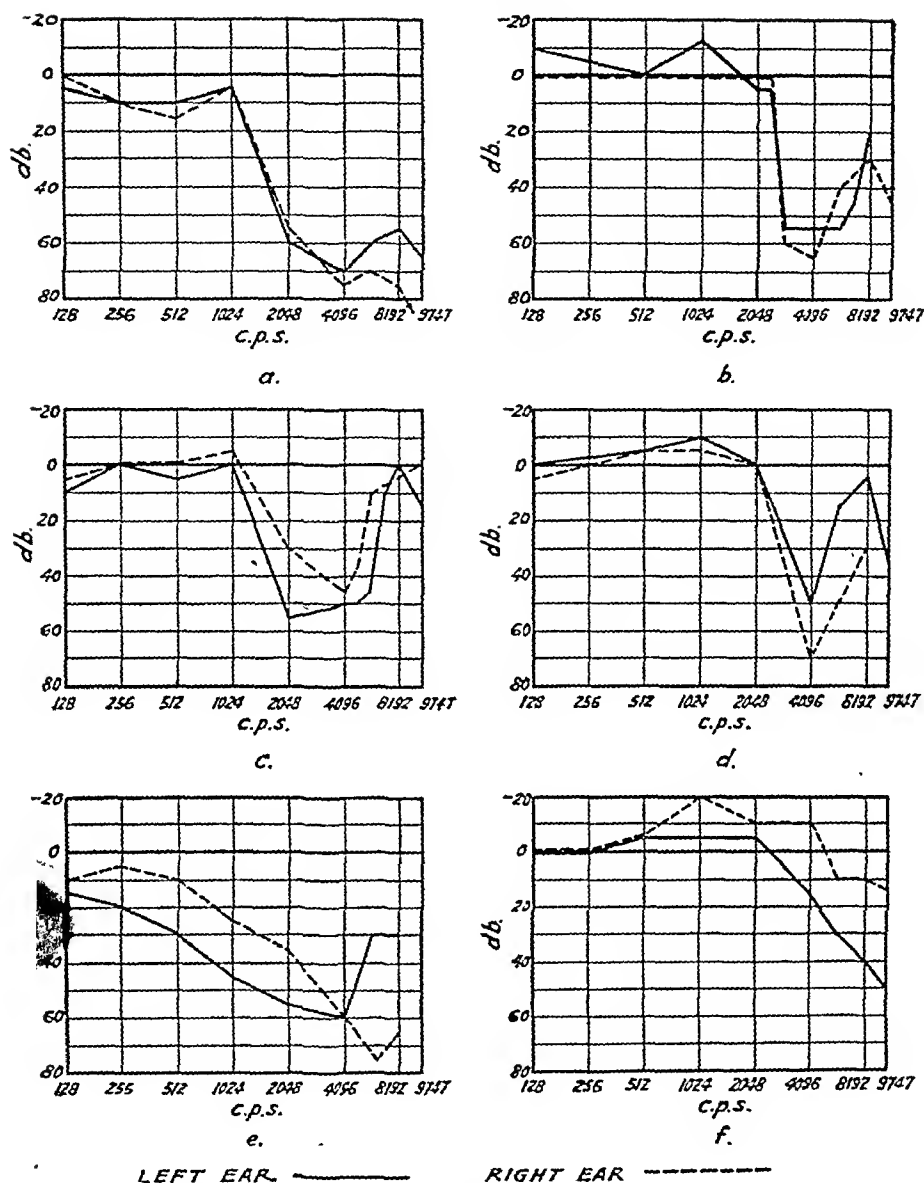


FIG. 8.

(a) Bdr. Billings, age 26. In artillery  $4\frac{1}{2}$  years in Middle East, Crete and Greece. In gun crew for 18 Pr., 25 Pr., and 4.5" How. In last  $1\frac{1}{2}$  years has been at proof range

(b) Bdr. V. V. Houston, age 23. In artillery for 3 years, mainly with 6 Pr. and 2 Pr. Tank-attack guns.

(c) Capt. R. M. Hoskins, age 32. In artillery for 4 years; 2 years since he has been in a guncrew position. Mainly 6" coast guns and 9.2" coast guns.

(d) Gunner A. Hampton, age 20. In artillery for  $2\frac{1}{2}$  years. For 2 years has been at a proof range.

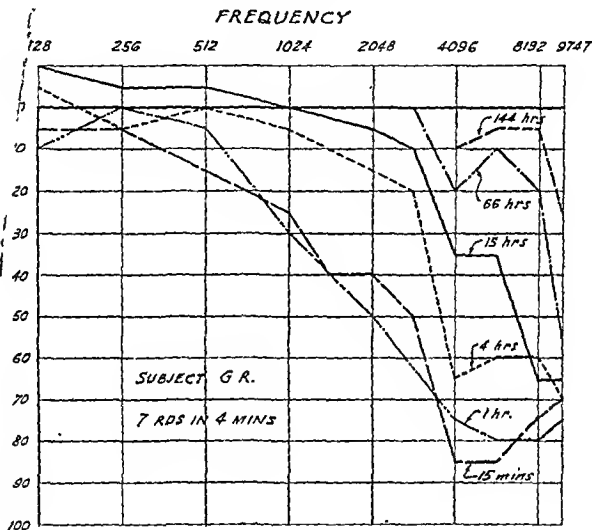
(e) Major Tyson, age 34. Connected with artillery for 16 years, but extensively in last 4 years in the latter  $1\frac{1}{2}$  of which he has been at a proof range. Has worn earplugs only in last 6 months.

(f) Sgt. Withers, age 27. In A.A. battery for 3 years with 3", 3.7" guns.

Audiograms of 6 subjects with permanent gunfire deafness.

## Temporary Deafness following Exposure to Gunfire

When the highest frequencies (8192 or 9747 c.p.s.) were the first in the final audiogram which resulted was usually one or other of those seen in Figs. 7b, 7e, 7f and occasionally 7a. Not uncommonly the frequency to be initially affected was not the one which showed the greatest hearing loss, a frequency involved later in the development of the deafness "overtaking" it (e.g., see Fig. 3b.)



**AUDIOGRAM AT VARYING PERIODS  
AFTER EXPOSURE TO 17 PDR. T/A GUN  
WITH MUZZLE BRAKE**

FIG 9

### 10. Recovery

Fig. 9 shows the complete audiograms for subject G R at various times after exposure to seven rounds in four minutes of the 17 Pr. tank gun with muzzle brake. Fig. 10 illustrates the rate of recovery



of the individual frequencies for the same experiment. Time has been plotted on a logarithmic scale. In Figs. 11 and 12 the average hearing loss for the range from 512 to 8192 has been plotted against the time after exposure on a logarithmic scale, in Fig. 11 for various exposures of subject G.R. and in Fig. 12 for various subjects.

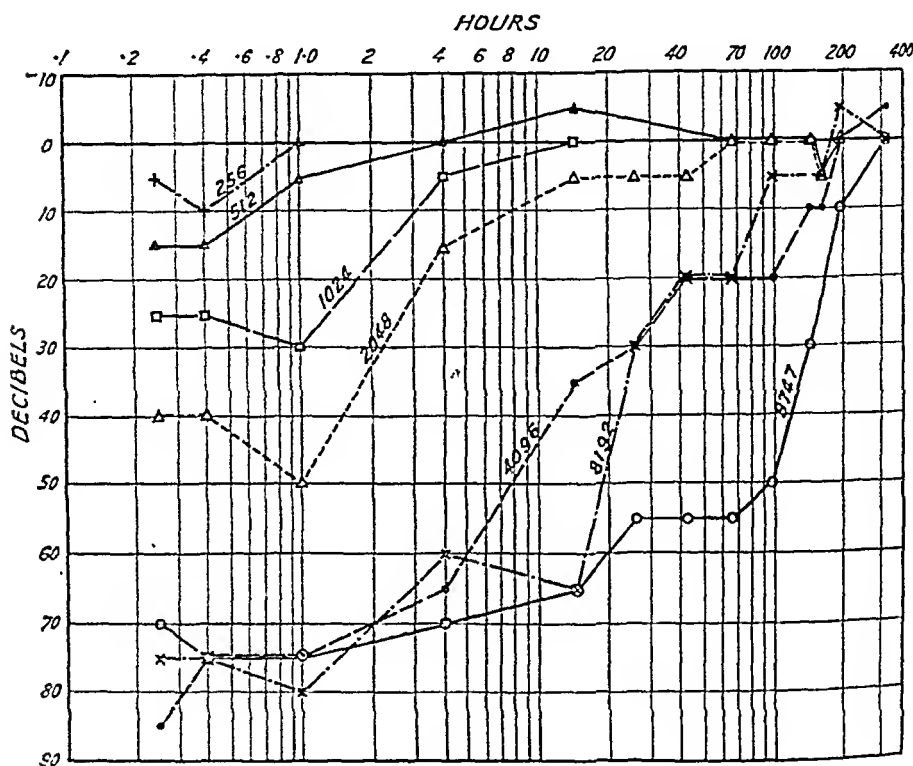


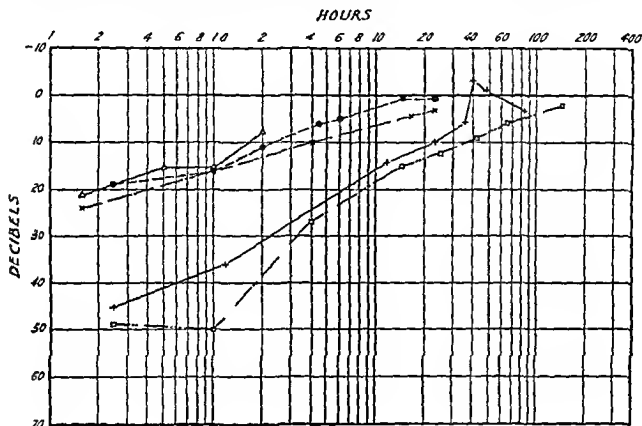
FIG. 10.  
Recovery curves of individual frequencies for subject G.R.  
after 7 rounds of 17 Pr. T/A Gun.

The time of recovery is shortest in the lower frequencies, and longest in the higher. When the deafness is as severe as that shown in Fig. 9, there is usually a lag of several hours before recovery commences in the upper frequencies. Occasionally the deafness increased in severity after exposure before recovery commenced. This is well exemplified after the exposure of the right ear of subject G.R. to fifteen rounds fired from the rifle in position A. In this instance there was a loss, at 2048 c.p.s. of 5 db. after fifteen minutes, but after three hours it had increased to 45 db. When the maximum loss occurred some time after fifteen minutes, it is indicated in Table I by the figures in parentheses below the values at fifteen minutes.

Figs. 10, 11 and 12 indicate that once recovery sets in its rate follows a roughly exponential curve.

# Temporary Deafness following Exposure to Gunfire

The last frequency to recover was usually either 9747, or in the region of 4096 to 5793 c p s. Not infrequently in the final stages of recovery two small gaps could be seen, one at 4096 and the other at 9747 c p s (see upper curve in Fig 8). The last frequency to recover in the experiment of Fig 9, was 9747 c p s and it had reached 5 db of the pre exposure level seven days after the exposure. Complete recovery of subject C W after the exposure on 15 8 44 (see Table 1) did not take place for eleven days, and that of subject K R on the 18 8 44 (see Table 2) did not take place for fourteen days.



- — — — ● 29-5-44 Left ear, 11 rds of 37 AA gun
- + — — — + 17-6-44 Left ear, 20 rds of 18 Pr gun in emplacement
- x — — — x 21-6-44 Right ear, 10 rds of 92 in Coast gun
- Δ — — — Δ 6-7-44 Left ear, 10 rds of Short 25 Pr gun
- — — — □ 29-6-44 Right ear, 7 rds of 17 Pr gun

FIG 11

Recovery curves of average hearing loss over range 512 8192 c p s for subject G R

Usually audiograms showing peak losses of the order 30 or 40 db recovered in 24 to 48 hours, and losses of the order of 20db commonly recovered in a few hours and sometimes within one hour. Fig 1 in the previous paper shows a number of audiograms 1 hour and 15-23 hours after exposure.

# G. Reid

TABLE 2.

Subject	Date	Firing Details	Hearing loss in Db. at :									
			Pos.	128	256	512	1024	2048	4096	5793	8192	9747
B.S.C.	8-9-44	12 rounds at 15' intervals	A.	5	-	15	10	60	55	35	25	25
	12-9-44	10 rounds at 10" intervals	A.	5	5	10	10	5	60	60	50	50
	19-9-44	10 rounds at 5' intervals	A.	5	0	0	5	0	40	25	30	15
	28-9-44	10 rounds at 10" intervals	A.	0	0	0	5	5	45	35	30	40
	3-10-44	10 rounds at 15' intervals	A.	5	5	5	5	0	35	20	5	20
C.W.	15-8-44	10 rounds at 10" intervals	A.	10	10	0 (20)	5	45	65	65	65	50
	28-8-44	10 rounds at 15' intervals	A.	15	10	20	20	30	35	45	30	-
	26-9-44	10 rounds at 10" intervals	A.	5	5	5	0	20	45	50	65	-
P.W.	18-9-44	10 rounds at 15' intervals	A.	5	0	5	0	30	35	20	15	45
	26-9-44	10 rounds at 10" intervals	A.	0	0	0	0	10	25	15	35	40
	2-10-44	10 rounds at 15' intervals	A.	0	0	0	0	5	15	0	0	20
	8-11-44	10 rounds at 10" intervals	A.	5	5	5	0	0	0	0	0	5
	24-1-45	10 rounds at 10" intervals	A.	0	5	0	0	5	10	10	10	10
J.A.	11-9-44	10 rounds at 15' intervals	A.	0	5	0	0	5	0	0	0	0
	18-9-44	10 rounds at 15' intervals	A.	10	5	5	5	10	0	15	5	5
	19-9-44	10 rounds at 10" intervals	A.	10	5	5	5	10	25	5	5	0
	20-9-44	10 rounds at 10" intervals	D.	5	5	0	5	10	5	-	0	5
	25-9-44	30 rounds at 10" intervals	A.	5	10	0	0	10	10	0	5	5
	27-9-44	50 rounds at 10" intervals	A.	0	-	5	5	10	15	5	0	20
J.	18-9-44	10 rounds at 10" intervals	A.	0	-	-5	0	0	5	0	15	0
	21-9-44	10 rounds at 5" intervals	A.	0	0	0	0	5	10	0	10	5
	21-9-44	50 rounds in groups of 10 with 5" between each round and 5" between each group	A.	5	-	5	25	55	50	25	40	30
	25-9-44		A.	0	-	5	10	20	0	10	40	20
	1-10-44	50 rounds in groups of 10 with 5" between each round and 5" between each group	A.	0	0	0	0	5	0	0	0	0
	11-44	50 rounds at 5" intervals	A.	-10	-5	0	5	30	50	55	55	60
	25-1-45	50 rounds in groups of 10 with 5" between each round and 5" between each group	A.	-	-	0	5	25	10	10	35	-

# Temporary Deafness following Exposure to Gunfire

TABLE 2—continued

Subject	Date	Firing Details	Hearing loss in Db at									
			Pos	128	256	512	1024	2048	4096	5793	8192	9747
C L F	12 9 44	10 rounds at 10" intervals	A	0	5	5	15	10	25	10	10	15*
	19-9 44	10 rounds at 15 intervals	A	0	0	0	0	0	15	10	5	15*
	4 30 44	10 rounds at 20" intervals	A	0	5	5	0	0	10	15	5	15*
H l e B	14 8 44	11 rounds at 15 intervals	A	-	-	0	5	35	40	30	15	15
	16 8 44	11 rounds at 10" intervals	A	0	0	0	5	15	55	65	50	55
	21 2 45	11 rounds at 10" intervals	A	0	0	5	10	20	50	55	55	60
R A W	9 9 44	10 rounds at 10" intervals	A	5	5	5	0	5	5	0	25	20
K B	26-9 44	10 rounds at 10" intervals	A	0	0	0	0	-5	0	15	5	10
G R	11 8 44	15 rounds at 15 intervals	A	-	-	0	5	10	15	20	45	45
	21 8 44	15 rounds at 10" interval	A	0	0	0	0	5 (5)† (10)‡	0 (35)† (45)‡	25 (25)‡	40	40
K R	18 8 44	7 rounds at 5 intervals	A	5	5	10	35	45	50	55	70	70
	21-9 44	7 rounds at 5 intervals	A	0	0	0	0	15	10	20	55	60
	28 9 44	7 rounds at 5 intervals	A	0	0	0	5	5	5	35	35	50
E P S	A large number of preliminary experiments too numerous to record											
	8 8 44	3 rounds at 15 intervals	B	0	0	0	0	0	20	10	15	20
	10 8 44	3 rounds at 15 intervals	A	0	0	0	0	0	40	15	30	35
		4 rounds at 15 intervals	A	0	0	0	0	0	40	30	35	40

\* Initial permanent loss greater than 30 db below audiometer zero

† 1 hour later

‡ 3 hours later

In following recovery curves the impression was sometimes formed that certain frequencies passed through a phase of hypersensitivity before settling down to the pre-exposure level

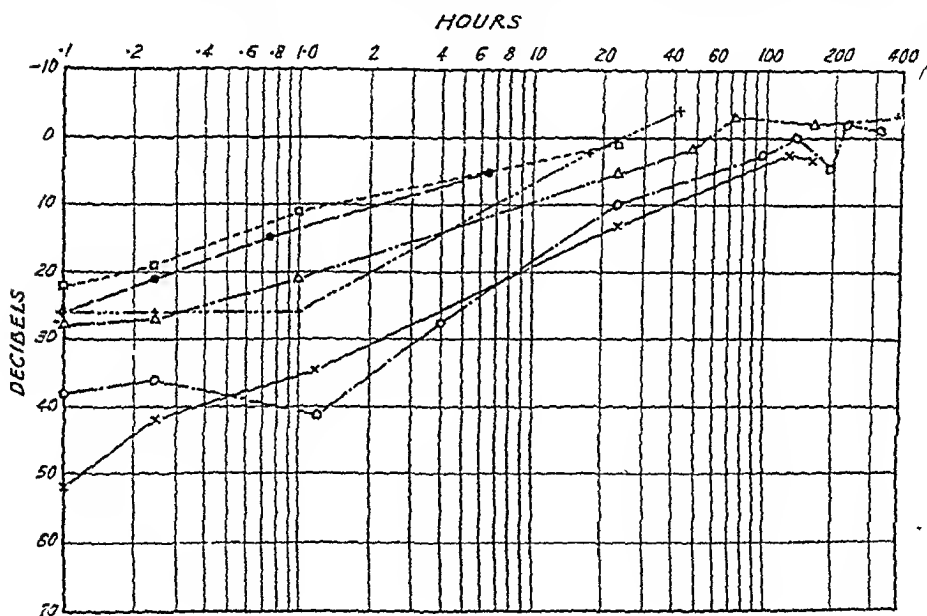
## 11. Onset of Permanent Deafness

The study of recovery curves leads naturally to a consideration of the mode of onset of permanent deafness. No serious permanent loss of hearing was produced as a result of these exposures, but with subject E P S, after an exposure resulting in a peak loss of 40 db the 4096 c p s range was still unrecovered twenty days after exposure. Usually in this subject a loss of this order recovered in less than two days. Recovery in both the 4096 and 9747 c p s ranges occurred at about the same rate and was complete in about the same time, sometimes the one and sometimes the other being the last to recover. On this occasion after the las

exposure recorded in Table I, recovery commenced in the usual way, the losses at various intervals after exposure being as follows:—

c.p.s./hrs.	.25	1.0	5.5	7.0	23	46	53	100	104	192
4096	40	35	30	25	25	30	30	25	20	25
5793	30	20	15	10	5	0	0	0	—	—5
8192	30	25	20	20	5	0	0	0	5	—5
9747	40	35	25	25	5	10	10	10	5	0

after twenty days there was still a loss of 20 db. at 4096 c.p.s. Unfortunately the subject has not been available to continue test, but two months after exposure he considered that his hearing had not returned.



△—...—△	12-9-44	B.S.C.	10	rounds	at 10 sec. intervals.
□- - - - □	28-9-44	B.S.C.	10	"	" 10 "
x—...—x	18-8-44	K.R.	7	"	" 5 min "
●—...—●	16-8-44	H.L.B.	11	"	" 10 sec. "
+—...—+	14-8-44	H.L.B.	11	"	" 15 min "
○—...—○	15-8-44	C.W.	10	"	" 10 sec. "

FIG. 12.

Recovery curves of hearing loss over range 512-8192 c.p.s., after exposure to blank rounds from rifle, position A.

# Temporary Deafness following Exposure to Gunfire

It is interesting to note that this considerable lag in recovery did not follow a particularly severe initial deafness, but during the thirteen days before the exposure under consideration he was subjected to seven exposures of the same or less severity, from each of which recovery occurred. This number of experiments was never made in so short a time with other subjects. The unforeseen result in this instance possibly throws some light on the development of permanent deafness. Although it is clear from the story told by deafened patients and from the results reported in the earlier paper (subject N E M), that one extremely severe exposure may result in permanent damage, this work indicates that it may also result from an exposure which in the past has led to deafness with recovery, if insults be sufficiently often repeated. Further evidence on this matter is, naturally, lacking.

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## CLINICAL RECORD

### MASTOID ASYMMETRY AND INNER-EAR DEAFNESS : AN UNUSUAL CASE

By NORMAN A. PUNT, R.A.M.C.

Private H. D., aged 19 years, stated that 8 months before admission he received a blow behind the right ear, possibly with a rifle-butt, which he thought caused unconsciousness for about half-an-hour. Next day he complained of pains behind the ear and noticed some swelling in that region. He doubted whether the ear discharged.

Six weeks later he was admitted to a military hospital ; according to the case-notes the pain and swelling (which had previously subsided) recurred and fluctuation was elicited. The tympanic membrane and hearing were noted as normal.

Three days later the notes state that " he had a sensation of something giving way in post-aural region and since then had no pain ; swelling over mastoid smaller, less red and not tender."

Thirteen days later he was discharged fit for duty the swelling having " practically subsided ".

His complaint when he came under my care (that is eight months after the injury) was of a swelling behind the ear, " tooth-ache " type of pains intermittently in that region and deafness in that ear. He had no headaches, tinnitus or vertigo. He associated his symptoms with the accident and stated that he had never had ear symptoms before, nor a swelling behind the ear. The deafness, he was convinced, was caused by the blow ; it was variable at first but became of constant degree. There was no history of any other trauma or illness.

*On Examination.* He appeared to be a fit man of average physique and intelligence and his pulse and temperature remained within normal limits.

His right pinna was displaced forwards by a post-auricular swelling apparently due to an expansion of the whole mastoid process, which was considerably larger than its fellow. The skin and subcutaneous tissues felt and looked normal ; there was no abnormal heat, redness or tenderness compared with the opposite side and the enlarged process felt bony hard (Fig. 1).

The external auditory meati appeared normal, that of the right being of slightly larger calibre than the left. The drumheads were intact and appeared normal and were mobile on using Siegle's speculum.

#### *Hearing Tests.*

Whisper voice R. 6 inches. L. 15 ft. (normal under conditions of testing).

Weber (C 256 & 512) lateralized  $\rightarrow$  L.

Rinne's (C 256 & 512) positive R and L.

Air conduction (C 256 & 512) some definite diminution on R.

## Clinical Record

Air Conduction (C 4096) considerable diminution on R

Absolute Bone Conduction (C 256 & 512) some definite diminution on R

*Labyrinth Tests* Caloric tests showed both labyrinths to be functioning. Apparatus for more precise hearing and labyrinth tests was not available, but the above findings seemed conclusively to show a severe right inner-ear type of deafness. Cranial nerves other than the right auditory, including the facials, appeared to be normal and his pupils were equal and reacted normally to light. The Kahn test was negative.

*X-ray Films* (Figs 2, 3 and 4) These showed the right mastoid bone to be considerably larger than the left. Both mastoids were of the cellular type and the cell-outlines and density appeared normal and equal on the two sides. No fracture-line could be seen, but this was not regarded as evidence that fracture had not occurred.

### SUMMARY AND CONCLUSIONS

A youth presented himself eight months after receiving a severe blow behind the right ear. He was found to have a marked enlargement of the mastoid bone and severe inner-ear deafness of that side.

It seems possible that the mastoid asymmetry was of developmental origin and that he had not previously been aware of it (the early traumatic swelling being due to a soft tissue injury), and that the deafness was due to cochlear or acoustic nerve trauma, alternative suggestions or reports of similar cases would be of interest.



## K. B. Bellwood

One ear, for instance, may have a tinnitus of a different pitch or quality from that of the other. "Crackling" noises are not classed as tinnitus by some, and they are produced by clonus of the intratympanic muscles, or fibrillations in them, or are the result of bubbles. The movement of an effusion will produce peculiar sensations or noises, or may deaden, or alter, temporarily, a true tinnitus already present. It is in the hyperplastic stage that these manifestations are most commonly encountered.

The deafness in subacute catarrh is greatly relieved by inflation, but rapidly returns. If the infection in the nose is dealt with, and regular inflation through the tube carried out, the catarrh passes away completely, and little or no residual change remains, and hearing restored. In the hyperplastic condition the deafness is very definite and inflation gives only a moderate improvement in the hearing, which passes off quite soon. If the eustachian catheter is used the air entry sound is rough and often in the earlier type of case, there may be muffled bubbling râles, and these are most persistent. It is this sort of case which requires myringotomy, followed by daily inflation with the catheter, provision being made by a suitably angled incision to maintain an opening for several days. Removal of the effusion by suction with a Weber's intratympanic catheter often fails owing to the glutinous nature of the material. A course of potassium iodide will usually help to liquefy these effusions.

In the chronic dry otitis media, the intensity of the tinnitus and its distressing and complex character in the older cases, is well known. The pitch of the sound goes higher than ever, while the deafness varies a great deal, but is worse than in the earlier forms already described. Inflation gives no relief whatever as regards the deafness, and the tinnitus may be made worse rather than better. Treatment of this state is disappointing.

Tuning fork and audiometer tests show pure middle-ear deafness in the subacute otitis media. In the next stage, a loss of bone conduction becomes evident in some cases, and the deafness has a "mixed" character; the "nerve" element in the earlier cases is not marked, and if they are successfully treated in the usual way, this nerve deafness has an interesting way of disappearing. This probably means that the loss of bone conduction is not due to a true cochlear loss of acuity, but in some way caused by "damping" brought about by indurations affecting the round or oval windows.

In the chronic dry cases the deafness has a true "mixed" nature, and the loss of bone conduction very marked.

### *A method of treatment*

This method finds its most useful application in the treatment of tinnitus. When the condition of the nose has been brought to the healthiest state possible, and proper ventilation established, and effusions cleared, and still the results are not indicative of satisfactory resolution, then the following method has a definite field of application. The local treatment advocated here, is based on an older method applied in a new way. It consists in the insufflation per tubam of a solution under fairly considerable pressure; this is necessary to distribute the substance thoroughly in the passages. A powerful pump is required for the purpose, giving controlled pressures up to one atmosphere. The pre-war type of Atmozon pump is used, the usual pumps at

present used for spraying are for the most part too weak for most of the cases. The Politzer bag is clumsy and rather difficult to handle.

## *Details of Method*

The nose is sprayed with 4 per cent cocaine, and then a curved wool carrier, mounted and soaked in a little 10 per cent cocaine, is carried back along the floor of the nose to engage in the tubal orifice, where it is allowed to remain for a few seconds. A suitable catheter is now chosen and passed into the tubal opening, and the pump union connected up, and sufficient pressure applied to get a satisfactory air entry through the tube, as heard in the auscultation tube. The pump connection is now removed and 5 to 6 minims of an argyrol-glycerin solution introduced into the catheter with a pipette.

R Argylol      gr 20  
Glycerin      3v  
Aq dest ad  $\tilde{5}$ i

The nozzle from the pump is now re connected, and the catheter held steady in the tube while the pressure is rapidly raised to a point where the solution is heard to enter the drum with bubbling noises, the amount of pressure being regulated according to sounds heard in the auscultation tube. The râles gradually diminish as the fluid is scattered. There is a sharp but not severe pain in the ear, which soon passes into a slight ache, disappearing in half an hour. Where there is unduly severe pain, intratympanic adhesions have been torn, and a small hypodermic of morphia is needed. In apprehensive and first cases premedication on these lines is desirable.

The catheter is now withdrawn and the membrana tympani inspected with a magnifying otoscope, a thick black line along the handle of the malleus should be seen, and usually a dark patch in the posterior segment. These signs denote a good distribution of the solution. Where there are thin areas in the membrane, a perfectly correct pressure may rupture them, but such accidents are not harmful except in that the distribution of the glycerin is impaired. The perforations heal quite well.

The co-operation of the patient is essential, as the procedure is not pleasant, but with good preparation and patience, he need be subjected to no serious pain.

An ordinary course of treatment consists of four insufflations at intervals of from two to four weeks, in each case.

The intervals are adjusted to the degree of reaction in the tympanum, for several days afterwards the membrane is hyperæmic. The dark solution disappears in two to three days. A second course or maintenance repeats may be given after an interval of several months where circumstances require it.

This treatment is most valuable in the hyperplastic stage. In the subacute cases insufflation on these lines is rarely necessary since ventilation and elimination of infection are all that is necessary to get a good result. The dehydration and hyperæmia induced by the solution is very efficacious in removing exudates and œdema, and in thus preventing later adhesions and fibrosis.

The method gives excellent results in the treatment of tinnitus in the hyperplastic cases, some perseverance is needed with those cases which have a

## K. B. Bellwood

longer history, and are, perhaps, approaching the interstitial change in greater degree.

The hearing is also improved in these cases ; the effect is quicker and better than with inflation alone.

With long standing cases of chronic dry catarrh the results are usually disappointing, but one occasionally gets a surprisingly good improvement in the hearing as well as in the tinnitus. The method is well worth a trial in those cases of severe tinnitus, as relief can be obtained with this symptom even if the hearing is unaffected.

Analysing the last hundred cases treated by this method over the last few years, the results are as follows :

Chr. Dry Catarrh	..	..	..	76	Tinnitus relieved	..	21
					Deafness relieved	..	12
Chr. Hyperplastic Catarrh	..	..		24	Tinnitus relieved	..	12
					Tinnitus cured	..	9
					Deafness relieved	..	17

## SOCIETIES' PROCEEDINGS

### THE SCOTTISH OTOLOGICAL AND LARYNGOLOGICAL SOCIETY

The Fifty First Meeting of the Society, held in the Ear, Nose and Throat Department of the Royal Infirmary, Edinburgh, on November 23rd, 1946.

*President* MR R P MATHERS (Dundee)

#### Congenital Short Œsophagus with Thoracic Stomach

By F T LAND

This brief communication is based on an investigation into the incidence of the interesting condition commonly referred to as congenital short Œsophagus, which is being carried out at the Glasgow Western Infirmary. I am indebted to my collaborators, Dr J B. Rennie of the Department of Medicine, and Dr S D Scott Park, the Radiologist, for permission to refer to data which we intend soon to publish, and to Dr Gavin Young, under whose care many of the patients have been.

During the last fifteen to twenty years, the occurrence of this abnormality has been noted and recorded with increasing frequency. On surveying the hospital records of cases of dysphagia for a period of nine years, we have encountered thirty-seven instances. In thirty of these, diagnosis seemed well established and characteristic X ray appearances were found. In the remaining seven, which occurred mainly in the earlier part of the period, the diagnosis seemed very probable, but the patients could not be followed up for further investigation. Peptic ulceration in the Œsophagus is a frequent accompaniment and indeed it occurs rarely in the absence of short Œsophagus with thoracic stomach.

In our series the sexes were almost equally affected. The age at onset of symptoms was two to three times more often over than under forty. Peptic ulcer at the lower end of the Œsophagus with associated spasm accounts for the characteristic symptoms. Pain was a complaint in two-thirds of our cases. It is usually felt at the lower end of the sternum at the time of swallowing, but may recur later when the patient bends or lies down, a feature which is of diagnostic importance. The pain may radiate to the inter scapular region, and more rarely, down the left arm. It is as a rule readily relieved by alkalis. The aggravation of pain on bending or on lying down is explained by incompetence of the abnormally situated cardia which allows regurgitation of acid gastric contents into the Œsophagus with consequent ulceration and spasm.

## Societies' Proceedings

Ulceration is sometimes attributed to acid secretion from islets of ectopic gastric mucosa in the œsophagus. It is interesting to note that peptic ulcer in the stomach or duodenum may co-exist: in four of our cases a duodenal ulcer was also present. Hæmatemesis occurred in nine cases and was a first and only symptom in three. Dysphagia was present in the majority, and in three cases occurred for the first time soon after gastro-enterostomy. I have recently seen another instance of this.

The condition may readily be missed if screening is carried out only in the upright position. The examination should be made in the supine or in the Trendelenburg position, and if the patient is instructed to bear down or if the abdomen is compressed, the supra-diaphragmatic pouch will distend. Outlining of the gastric rugae by the barium in the thoracic part of the stomach is a valuable diagnostic feature. The existence of an ulcer can sometimes be demonstrated radiologically. There is generally spasm immediately above it which may temporarily obscure it at œsophagoscopy. The broad outline of the flow of barium into the gastric pouch contrasts with the trickle through the cardia in achalasia.

Confusion with carcinoma is possible, particularly if the appropriate radiological technique to demonstrate this abnormality has not been employed. A few of the earlier cases in our series were not at first recognized, and were treated by radio-therapy. An active peptic ulcer or the scar of the healed one may be seen at œsophagoscopy, and biopsy revealing the presence of gastric mucosa is confirmatory.

In two of our cases adeno-carcinoma had developed in the thoracic stomach. There are very few records of this occurrence.

The ætiology of short œsophagus with thoracic stomach requires further elucidation. That it is a congenital lesion is indeed not conclusively established. The usual age at onset of symptoms does seem to throw doubt on its probability, although the condition has been recognized by Brown Kelly and others in infancy and early childhood. Johnston has suggested that fibrosis and spasm secondary to ulceration result in shortening, a portion of the cardiac end of the stomach being pulled up into the thorax. It is true that the lower end of the œsophagus enjoys considerable freedom of movement in the diaphragmatic hiatus, but apart from other considerations, e.g., the occurrence of the condition in the apparent absence of ulcers or endoscopic evidence of fibrosis, it is hard to believe as Hurst argues, that limited fibrosis should result in longitudinal contraction of a mobile œsophagus rather than in stenosis and fixation by surrounding adhesions.

It has been suggested that the condition is a sliding hernia and that the fundamental lesion is laxity of the diaphragmatic hiatus. Favouring this explanation is the usual age at onset, the occasional occurrence of symptoms following abdominal operation, and the fact that the presence of a thoracic stomach is quite rarely noted at autopsy, even in cases where its existence has been clearly demonstrated during life.

In this short paper I have not attempted to do more than to indicate the incidence of this abnormality and to summarize its principal features, but I hope that what I have said may form a useful basis for discussion.

The paper was illustrated by lantern slides of X-ray films and diagrams.

# The Scottish Otological and Laryngological Society

## Short Œsophagus with Thoracic Stomach

By DR TOM O HOWIE

There are two types —

(1) *Congenital* These may be divided into two groups —

(a) Those diagnosed early They are seen in children and both sexes are represented

(b) Those diagnosed late Those occur in adults, and usually become manifest after forty years of age Females are mainly affected, and there may be some connection here with endocrine disorders I notice that this differs from Dr Land's series of cases in which male and female are represented almost equally

*Body types* In the early cases it is usually found in children of the asthenic, thin type, while the late congenital cases show in the broad, pyknic type of patient

(2) *Presumed acquired* This is still theoretical and requires to be worked out by investigation

It differs from post-traumatic and post operative displacement of the lower end of the œsophagus The changes may be due to a reflex from intra-abdominal pathology, e g, liver, gall bladder, pelvic tumours and ovarian cysts, pointing to a neurogenic diskinesis from abdominal reaction between the para- and vagal- sympathetic co ordination It is usually symptomless, and is only found in radiographic examination of the œsophagus, and only gives dysphagia in the late stages It is sometimes seen in systematic disease due to neuro-enteric disfunction leading to shortening and epidiaphragmatic herniation This may be found in scleroderma acroparæsthesia and acrocyanosis . In these cases the functions of the cervical sympathetic system are often upset

The important point which is not often enough stressed is that pseudo-angina, i e cardiac effort syndrome without cardiological evidence of disease may be caused by a short œsophagus or an epidiaphragmatic hernia with thoracic stomach

Examination of cases with pseudo angina have shown these conditions in from 15 to 20 per cent

Dr Blum, Assistant Radiologist at the Victoria Infirmary, has been particularly interested in this condition He has examined about 4,000 cases during the past three years from this angle, and in slightly over 1 per cent has found some pathological condition of the lower œsophagus, excluding carcinoma, achalasia and benign strictures He found forty cases of frank short œsophagus of congenital or acquired type Of these he considered 20 per cent were acquired, while 80 per cent represented the congenital group This excludes para-œsophageal and traumatic diaphragmatic hernias, and cases of gastrectomy which showed some post-operative œsophageal shortening Of the congenital type 16 per cent of cases occurred in children below twelve years of age Evidence of incarceration and ulceration is uncommon, only two cases being definitely established Carcinoma was found in the thoracic stomach in

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one case. I shall return to this shortly. None of these findings occurred in any of the "presumed acquired" cases.

He stresses that this condition of short œsophagus should be looked for in cases with abdominal complaints, and in neurological conditions where para- and vagal-sympathetic systems may be in disfunction and diskinctic, since this often shows in other organs, for example, the ureter, gall bladder and colon. There may be some similar disturbance in the mega syndrome, as it affects the colon and œsophagus. All cardiac conditions with angina unexplained by a cardiological examination should also be investigated from this point of view.

I would just like to mention a case which I saw with Mr. Mailer in the Victoria Infirmary. He has been good enough to allow me to discuss it here, since he hopes to publish it more fully later.

The particular interest of this patient, from our point of view, is that she had a condition diagnosed radiologically as a para-œsophageal hernia. On 16.4.46 Mr. Mailer closed the hiatal hernia, and had a little trouble in retaining the stomach in the abdominal cavity. The patient was troubled thereafter with considerable flatulence and vomiting. Further radiological examination showed that the hernia appeared to have recurred, and it was definitely stated that there were no signs of shortening of the œsophagus. On 5.6.46 I examined her by œsophagoscopy. The œsophagoscope passed easily to 31 cm. The gullet wall was slightly atonic and sodden. The displaced cardia was discovered reacting normally at 31 cm. from the upper teeth. It was slightly patulous. The fore-stomach was entered just below the cardia and a few polypoid growths were noted. Biopsy was taken from them, and gastric mucosa was easily recognized below this area.

The patient was considered to be suffering from a short œsophagus, about 5 to 6 cm. less than normal. Her vomiting was unlikely to be due to the difficulty of food entering the fore-stomach, and was more likely to be caused by the operative narrowing of the hiatus in the diaphragm. The pathological report on the biopsy showed that the tissue represented a mucoid adenocarcinoma from the thoracic stomach. On 28.6.46 Mr. Mailer by a trans-thoracic approach found an indurated growth involving the thoracic stomach and the lower end of the œsophagus. It was slightly adherent to the neighbouring structures. He was able to break down these adhesions and brought up the stomach through the diaphragmatic opening by enlarging the hiatus in the diaphragm. He resected the growth and carried out an anastomosis between the œsophagus and the stomach. The patient made a slow but steady recovery, and is now eating a normal diet.

This case first illustrates the importance of an œsophagoscopic examination before completing the diagnosis of short œsophagus or para-œsophageal hernia, and second, it holds out some hope for cases of carcinoma in the lower inch or two of the œsophagus, which, in the past, we have been unable to help very effectively.

Dr. I. SIMSON HALL: *Four Cases Illustrating Results in the Treatment of Otosclerosis by the Fenestration Operation.*

(1) J. R. Operation 1.7.38. Pre-operative audiometer chart is not

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available as the hospital did not possess one at that date This operation was done with a hand lens and scraper

(2) Mrs M Fenestration operation 12 7 39 right ear Right ear was the worse of the two but is now the ear relied upon entirely This case is classed as a failure for statistical purposes, but illustrates very well the fact that this operation may arrest the progress of deafness although improvement is not obtained

(3) R H, æt 22 Fenestration operation 18 45 right ear Present condition audiometer charts

(4) Miss J B Bilateral fenestration operation--right ear 28 11 45, left ear 9 10 46 This patient suffered a facial paralysis after the first operation, which cleared up in about ten weeks

## DISCUSSION

Dr SIMSON HALL said that the cases which he had shown had been selected out of a very large number in order to show results of the operation in various types of cases, and one in particular, to show that even although improvement has not been obtained arrest of the deafness was achieved

Dr MARTIN had raised an interesting point in quoting two cases which improved in hearing after a diagnosis of otosclerosis had been made but he (Dr Hall) was in agreement with Albert Gray that the diagnosis of otosclerosis is never a certainty until the specimen has been examined under a microscope, and therefore he thought that the cases quoted by Dr MARTIN were not otosclerotics at all

The question of the most suitable type for operation was difficult to state briefly Dr Hall certainly does not recommend too hasty a decision to operate A patient showing a marked loss of the upper tones is definitely not a case for fenestration He also recommended that only when one is satisfied that a patient is approaching the point of social disability should one decide to do the fenestration operation This of course, applied mainly to the younger groups such as the case of the young man shown that afternoon This young lad was up against it economically He could not attend his classes and thereby finish his training but the operation had allowed him to regain his hearing and thus finish his training If he had been left alone the hearing might have returned in part after a period of years but what good would that have been to him? By then he would have left the University and gone into some work where his deafness would not be a disability In the younger patient fenestration was the answer when deafness was a social disability In the older patient Dr Hall could not give any rules as to which patient should have the operation and which should not

Mr VENTERS said he would like to congratulate Dr SIMSON HALL This question of fenestration was becoming a social difficulty What with the *Reader's Digest* and the Sunday papers he had one or two patients a week asking him about the advisability of the operation and the question would arise as to who was going to do this work It was time consuming both as regards training and the actual time of the operation

The first case he had had done by Dr Hall was a young girl of 20 who



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simply could not converse at all. She led an isolated life, working as a copying typist, and riding horses as a recreation to get away from people. She was becoming introspective and difficult. The operation had been performed and was a hundred per cent. successful. She had nursed throughout the war; there had been no difficulty with her training and she was now a lady almoner in London.

Dr. RITCHIE PATERSON said he would like to add his congratulations to Dr. Hall. It so happened he had seen the lad of 22 many years ago and they had recognized each other this afternoon. The patient had told him what a difference the operation had made in his life and he could well believe this as when he had seen the boy in the Glasgow Ear, Nose and Throat Hospital he had been very deaf. When he saw the boy this afternoon he thought it a pity there had not been an audiometer available similar to the one in use in the Infirmary, Edinburgh. If any one present at the Meeting had the ears of the Ministry of Health, he wondered if it would be possible for such a person to suggest making audiometers all of one pattern for hospital use. If the audiometers were of a universal pattern and calibration, it would be possible to interchange graphs of the patients. He (Dr. Ritchie Paterson) used a 2 B.E. audiometer and found it had not sufficient intensity for very deaf patients who might require operation. The question of otosclerosis was one which had given considerable difficulty. Some people think that otosclerosis can improve through a reversible process though most people think this is not the case. He remembered asking the late Dr. D. Greig Grant, after a lecture on bone disease, if he thought the bone disease known as otosclerosis might improve on its own and he seemed to think a reversible process might take place. If one thinks of an operation in which a fenestration operation is not made—a mastoid operation where decongestion of the parts takes place so that there is a change in nutrition of the labyrinth from fresh blood—would this cause any change in hearing? One is conversant with the chronic suppurative otitis media who has a mixed middle- and inner-ear deafness as well which show improvement after the removal of the mastoid bone without touching the middle-ear structure. It seems that the subject is a very interesting one.

Recently Dr. Ritchie Paterson had seen a patient with a new type of deafness. This patient had taken large doses of Vitamin B<sub>1</sub> over a period of six months. One year later he came to Dr. Ritchie Paterson complaining of deafness of the nerve type. The patient was a doctor and could not hear through a stethoscope. After some questioning, he remembered taking large doses of Vitamin B<sub>1</sub> on account of neuritis. Dr. Ritchie Paterson suggested he should go away and take large doses of Vitamin B<sub>1</sub> for two weeks. When he returned the deafness had disappeared and the hearing was back to normal.

Dr. R. SCOTT STEVENSON said that as regards the treatment of otosclerosis he was still inclined to say to try lip-reading and a hearing-aid; but if the patient would not learn lip-reading—and many adults found it difficult—and could not bear a hearing-aid, he certainly recommended the fenestration operation, from which he had seen a number of remarkably good results, as well as some failures. Contrary to a general impression, he had found at his hearing-aid clinic in London, by careful testing by voice and audiometer, that

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the hearing of most deaf patients using a hearing-aid improved and did not deteriorate

Dr BROWNLIE SMITH said there was no doubt, as Dr Hall had shown, that the operation could bring back the patient's hearing and, in suitable cases, this improvement in the hearing could be retained. The difficulty was in the selection of the cases and he was particularly interested in Case No 3. The operation had been done in 1938 and now the ear which had been operated upon was regarded by the patient as the better ear although it was probably the worse ear at the time. On the other hand, the audiometer chart showed no marked deterioration in the hearing of the opposite ear so that it would appear the disease was not very progressive. He himself had recently seen a patient on whom he had performed the operation in 1937, and had reopened the fistula a year later. When examined some months ago the ear on which the operation had been performed was again the worse ear although there had been very marked improvement at the time. It did not always follow that the ear on which the fenestration operation had been carried out remained the better ear.

## *Three Cases Illustrating Problems in Laryngeal Reconstruction*

(1) E McA. Complete stenosis of larynx. Cause—cellulitis of the neck, followed by perichondritis of the neck, tracheotomy and complete occlusion of the airway.

9 4 46—Operation laryngofissure. Excision of scar tissue in the subglottic region and insertion of skin graft on a sponge rubber mould. Fourteen days later mould removed and acrylic resin obturator inserted. Present condition.

(2) Mrs A A. Bilateral abductor paralysis treated by McCall Gardner modification of 'King' operation.

1942. Thyroidectomy followed by bilateral abductor paralysis necessitating tracheotomy.

17 3 44 Operation

22 3 44 Tracheotomy tube removed

8 5 44 Tracheotomy opening closed by pedicle flap

(3) Mrs R. For comparison with above. Bilateral abductor paralysis treated by the anterior transplant method.

## DISCUSSION

Dr RITCHIE PATERSON said he was very interested in these cases. He had operated on one case where following on a thyroid operation there had been a bilateral paralysis. Two similar cases he had seen had been treated with graduated metal bolts from the tracheotomy opening. These had been left in position for a week or two and then removed. In one case an inflammation had been set up with a local cellulitis in the subglottic area, but the end result of the case had been very good because after a period of seven years the voice was good and the patient very well.

## *Series of Four Cases Illustrating the use of Penicillin in Acute Frontal Sinusitis*

(1) Miss A A W, admitted 21 4 45. History—severe left frontal headache

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three weeks : painful swelling over left upper eyelid one week. X-ray showed opacity of both frontal sinuses and dubious erosion posterior wall right frontal. Catheters inserted into both frontal sinuses by small incisions externally. L.P.—C.S.F. turbid.

Penicillin—I.M. drip 100,000 units in 24 hours. Local 2,000 units 4 hourly. Culture—Staph. aureus.

30.4.45. Tubes removed. washes sterile : C.S.F. 4 cells per c.mm., but very slight papilloedema noted.

13.5.45. Slight left facial paralysis, and increase of papilloedema.

15.5.45. Operation—Mr. Dott. Obliteration of frontal sinuses and removal of frontal osteitis. Penicillin resumed systemically and locally.

30.5.45. Operation—Mr. Alexander. Frontal lobe abscesses drained.

18.7.45. Wound healed. Penicillin—systemic 200,000 units : local 312,000 units.

24.9.46. Frontal acrylic plate inserted.

(2) J.W., 14. Severe frontal headache and vomiting, four days. On admission complete closure of left eye with oedema.

Operation.—Intranasal drainage of left ethmoid. Left intranasal antrostomy.

Culture—Staph. aureus.

Sulphadiazine in full doses.

20.5.44. Operation.—External ethmoidal drainage, on account of spreading frontal oedema. Small catheter inserted into frontal sinus through trephine opening. Pus in frontal sinus.

21.5.44. Sulphadiazine stopped and penicillin commenced systemically and locally.

5.6.44. Wound healed : nose clean. It is to be noted that improvement had commenced before penicillin was started, but penicillin was given to test the possibility of clearing up a pus filled sinus without radical measures.

Penicillin—local, 10,000 units 4 hourly. Systemic 90,000 units 24 hourly.

(3) D.L., æt. 12. Admitted 21.8.45. Acute frontal sinusitis with oedema over the sinuses spreading up towards the hair line.

Operation.—Small incisions over the inner canthus and small tube inserted into the sinuses.

Four-hourly instillation of 10,000 units penicillin.

Completely cleared up and discharged from hospital 21.9.45.

(4) J.C., æt. 18. Admitted 22.2.46 for right Schwartze for sub-acute otitis media (Dr. Smith).

12.3.46. Discharged to Convalescent Home.

18.3.46. Readmitted with swelling above left eye and frontal headache : T. 103°.

19.3.46. Left frontal sinus drained externally, and tube for penicillin inserted—10,000 units 4 hourly : systemic, 90,000 units daily.

Bacteriology—hæmolytic streptococcus.

X-ray showed opacity frontal and maxillary sinuses.

8.4.46. Operation.—Double radical frontal (Dr. Sugar), rendered necessary because of discharging sinus and spreading osteomyelitis. An extradural abscess was found behind the right frontal sinus.

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11.4.46. Paresis of the left hand. C.S.F. 600 cells.

12.4.46. Extensive frontal craniectomy (Dr. Alexander). Extra- and sub-dural abscesses drained. C.S.F. 600 cells per c.mm.

Penicillin continued, local and general, also sulphamezathine given.

24.4.46. Further temporal and parietal craniectomy required to open and drain abscesses.

14.6.46. Discharged : all wounds healed. Only neurological abnormality is slight exaggeration of reflexes in left lower limb.

## DISCUSSION

Dr. LUMSDEN said the Society was indebted to Dr. Simson Hall for showing these cases. He had been particularly interested in the bacteriological findings ; in two there had been a staphylococcus aureus and in one a hæmolytic streptococcus. In 1943, Williams and Nichols of the Mayo Clinic (*Proc. Staff Meetings Mayo Clinic*, 1943, xviii, 467) reported two cases of spreading osteomyelitis of the frontal bone treated with penicillin. Anaerobic streptococci had been found in the spreading edge of the lesion, while staphylococcus aureus may also be present in the older suppurating area. The staphylococcus aureus was rarely responsible for the spreading type. This had come to his notice when he had under his care a Flying Officer with spreading osteomyelitis of the frontal bone. This patient had received sulphadiazine from the early stage (250 grams). After ten days he had performed a frontal obliteration and extensive bone removal. The culture had given staphylococcus aureus. The condition progressed. Two and a half weeks later there was a further removal of bone with exposure of dura. Four weeks later still, there was involvement of the parietal bone and the patient was in very poor condition. At this time, anaerobic culture gave a growth of hæmolytic streptococci, sulphonamide-resistant but penicillin sensitive. The patient was given two million six hundred thousand units of penicillin and there was marked improvement 24 hours after commencement and an uneventful recovery thereafter (*Jour. Laryng and Otol.*, 1945, lx, 108). It was desirable to have anaerobic cultures done in these cases.

Dr. HENDERSON had had one experience of this condition, when culture from the pus in the sinuses showed streptococci, from the bone staphylococci, while in the extra-dural abscess there was hæmolytic streptococci.

## *X-rays of Patients showing Osteoma of Sphenoidal Sinus.*

Severe headache of vascular type, and commencing changes in the left eye, compelled operative interference. Tumour was approached by the trans-septal pituitary route (Mr. Norman Dott), but access was insufficient, especially for the left sphenoid.

Approach was then made through the right ethmoid (I S.H.), crossing the skull, and the tumour was successfully removed.

The tumour was mixed cartilage and bone, and is reported by Col. Harvey (R.C.P. Lab.) as basically malignant in character. Patient at present is well and at work and is to have a course of deep X-ray treatment. Slides shown.

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## DISCUSSION

Dr. J. P. STEWART asked if there was anything abnormal in the nasopharynx, because the X-ray rather suggested something in the floor of the sphenoid.

Dr. HALL replied that there was no abnormality in the nasopharynx. The symptoms were those of headaches and eye symptoms due to pressure, but no other symptom was present.

Dr. A. B. SMITH.—*Exhibit*

Radiographs of a case of Gradenigo's syndrome treated by Frenckner's method. (Approach to the petrous tip obtained by route through the nucleus of the superior semicircular canal.) Patient alive.

No discussion.

### *Case of Hæmangioma of Palate.*

Patient reported with a vascular swelling of soft palate. Treated with insertion of Radium Needles, 9 mgrs., for two days. The condition shows little if any, change.

No discussion.

### *Case of Leishmaniasis.*

Patient has served in Forces in Southern Italy and Iraq and reported to the E.N.T. Department on *March 6th, 1946*, when he had ulceration of the anterior part of the nasal cavity, involving the septum and the right inferior turbinal. There was also a reddish indurated area on the right cheek. X-ray of sinuses showed membrane thickening of the right antrum. A piece of tissue was removed from the gums and from the nasal cavity and sent for pathological examination. This was diagnosed as almost certainly tuberculosis. Wassermann and Kahn tests were negative and swab from the gums produced a growth of yeasts with a few diphtheroids and staphylococci.

As the condition did not appear clinically to be of the nature of tuberculosis, further pieces were removed and again reported as showing tuberculous infection.

Patient was referred to the Skin Department, where the condition was diagnosed as one of Leishmaniasis and the Leishman-Donovan bodies were found in scrapings from the area affected. Treatment by X-ray therapy was commenced in the Skin Department.

No discussion.

### *Case of Tuberculous Rhinitis.*

Patient reported first on *August 28th, 1945*, with crusting on both sides of the nose, some atrophy and granulations appearing on the left inferior turbinal. A piece of tissue, removed for pathological examination, showed the condition to be one of tuberculous rhinitis. Patient was treated with diathermy on *November 15th, 1945*, and the condition progressed.

On *April 24th, 1946*, she was started on large doses of Calciferol, 150,000 units daily. The condition has now improved very markedly and we have been able to reduce the dose.

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## DISCUSSION

Mr JOHN GERRY said he was very interested in this case as they had been using Calciferol for lupus cases and the results had been very encouraging. The dose they had been using was up to 150,000 units a day. The blood should be examined every two months. He had been speaking to Dr Anderson, the skin specialist, who thought the results very good. In certain cases they had been using it for tuberculosis and in some quarters he believed it had been used for bone and joint tuberculosis. Personally he was always careful about any toxic effect. The first sign of this was usually that the patient had a feeling of being out of sorts but no actual sickness. This was followed in a short time by violent vomiting and hypercalcaemia. The only contra-indication to the treatment was if the patient showed any arteriosclerotic changes or any cardiac disease. All the cases in Aberdeen had done very well on calciferol.

Dr J P STEWART—*Acute Suppurative Otitis Media and Mastoiditis (R), Manifest Diffuse Labyrinthitis Meningitis Recovery*

R W, æt 15. History of discharging right ear for ten days, and deafness. Had an operation on the right mastoid eleven years ago. Has been treated with M & B.

18.12.45. On examination thick pus present in the right external meatus. Central perforation. No bulging of mastoid scar.

19.12.45. Reopening of Schwartze mastoid operation (R). Pus found in group of cells in tip. Lateral sinus exposed and found healthy. Wound stitched.

20.12.45. Nystagmus present and vomiting. Temperature 104°, pulse 120. Patient is delirious. Neck rigidity present. Kernig positive. Nil in discs. Lumbar puncture—fluid slightly turbid. Pressure 230 mm, cell count 800 per cm, a number of polymorphs and some lymphocytes seen.

No growth obtained on culture. Diagnosis of manifest diffuse labyrinthitis and meningitis.

Wound reopened and radical mastoid operation performed. Neumann's labyrinth operation, combined with West and Scott's trans-labyrinthine drainage for the C.S.F. Wire drain inserted into the cranium and good flow of C.S.F. established. Wound left open and patient put on intravenous and intrathecal penicillin, and sulphathiazole orally. Facial paresis noted on the right side.

Progress—The C.S.F. continued to drain freely and lumbar puncture on 30.12.45 showed a cell count of 60 per cm—cells chiefly polymorph.

2.1.46. Wire drain removed and wound stitched up. Operation cavity granulating up well and clean.

24.1.46. Posterior wound healed and patient discharged to convalescence.

12.9.46. Granulation tissue still present in mastoid operation cavity. Conservative treatment.

## DISCUSSION

Mr VENTERS said he had been frankly distressed by this case. He was under the impression that the West-Scott operation was somewhat obsolete. Since the advent of the sulphonamides he had seen five cases of chronic suppurative otitis media with suppurative labyrinthitis and circumscribed meningitis.

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Of these five cases, two showed hæmolytic streptococci in the cerebrospinal fluid and in the other three the fluid was sterile. In four cases he had carried out an ordinary radical mastoid operation with a labyrinthotomy—the Hinsberg operation—together with intensive sulphonamide chemotherapy. These four cases made an uneventful recovery.

Two weeks ago he had seen a patient with a history of a discharging ear for forty years. Clinical examination showed a suppurative labyrinthitis with circumscribed meningitis and the patient was so ill that no detailed examination could be carried out. He had done a radical mastoid operation, but had not completed the Hinsberg. The patient was given sulphonamide and penicillin. The operation had been done without waiting for the result of the examination of the cerebrospinal fluid. The fluid was opalescent and under pressure but the bacteriological examination proved negative. To his astonishment the following day the patient was sitting up in bed reading the newspaper, and he made an uneventful recovery.

In the light of these cases it would appear that the somewhat destructive operation, with little hope of preventing a facial paralysis, was rather unjustified.

Dr. HALL said he wondered if Dr. Stewart had not his tongue in his cheek when he produced this case. With the coming of penicillin we would have to reorientate ourselves as to the treatment of this condition. In the past we had been used to doing a labyrinthotomy or trans-labyrinthine drainage as a last hope, but we would have to give up this type of surgery and treat the patients with the more hopeful method of chemotherapy. In this way we might succeed in preserving function which this type of operation destroyed.

Dr. BROWNLIE SMITH said that the proof of the pudding was surely in the eating and it could not be said that the treatment was wrong when the patient was alive to-day after a very serious and dangerous illness. But he still wondered why Dr. Stewart had performed trans-labyrinthine drainage and had not treated the patient by penicillin and the sulpha drugs without opening into the meninges.

Dr. STEWART, in reply, said he had shown this case in the hope of stimulating a discussion, and it would appear he had succeeded. He performed the West and Scott operation for drainage of the labyrinth in this case as he considered it the most efficient treatment where meningitis followed a labyrinth suppuration. In the past this operation, when carried out in this type of case, yielded very successful results, provided it was undertaken early enough, though one was apt to get a facial paresis following it. He was sure that the patient would rather live with such a disadvantage than take the risk of death with his face straight, and in any case the functions of the labyrinth would be destroyed by disease so one could hardly call it a mutilating operation.

In reply to Dr. Hall: Neumann's operation is not obsolete in this country but it is performed less often than Hinsberg's operation, possibly because it is a more difficult and intricate one to perform; far from being more liable to injure the facial nerve, it is quite the opposite as one is working farther away from this nerve than in a Hinsberg operation. The continuous drainage relieves the headache and as the cerebrospinal fluid under tension retards the

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natural functions of the brain, these too are permitted to function more normally. He personally thought continuous flow of cerebrospinal fluid gave better results than intermittent drainage.

## *Osteoclastoma in Association with Paget's Disease of the Left Ethmoid Bone*

Mrs. E. B., æt. 66, complained of deafness of many years duration, discharging ears during childhood, nasal obstruction for the past three years. She had a polypoid growth removed from the nose in 1943—reported on as a giant cell tumour growth. Eight years ago had a fracture of the left femur, when Paget's disease was diagnosed. The circumference of the head has greatly increased, especially in the temporal region. Six months ago swelling was noticed over the left malar bone.

17 to 46. On examination there was a polypus-like growth blocking the left nostril which was hard in consistence. A healed scar was present in each drumhead and a middle-ear type of deafness was present.

X-ray report. Owing to Paget's disease it is impossible to obtain satisfactory views of the sinuses. The right antrum appears clear but the left is opaque. There is opacity of the posterior ethmoidal cells on the left side. A film of the pelvis confirmed the presence of an advanced degree of Paget's disease. Films of the chest showed chronic bronchitic changes.

23 to 46. Cherry coloured growth, very firm in consistence, removed from the left side of the nose. The growth extended into the ethmoidal bone.

Report on the microscopical examination of tissue removed at operation states that the features are those of Paget's disease complicated by a giant cell tumour or osteoclastoma.

X-ray plates and microscopical section of growth on view.

No discussion.



## ROYAL SOCIETY OF MEDICINE—SECTION OF OTOTOLOGY

November 1st, 1946

*President*—H. V. FORSTER**Otology in School Children and Child Welfare**

By H. V. FORSTER (Liverpool)

THOSE about to undertake the practice of Otology at the request of a local Education Authority will find special interest in the work of the late Dr. Kerr Love (1919) a past President of this Section. This is a record of three years' work in the treatment of ear disease, undertaken for the Glasgow School Board between the years 1912 and 1915. It is, to quote the author's words: "Essentially an essay on the Prevention of Deafness. Before the ink is well dried on its pages a Ministry of Health may be at work and it is the writer's wish that the progress of the new service will be such as soon to render the teaching of the book out-of-date.

Kerr Love was also asked for his advice on the treatment of ear disease in the schools under the control of the Secondary Education Committee of the county of Dumbarton, though the chief object of the Committee was to have cases of tonsils and adenoids treated by operation. My own work in Lancashire in the year 1919 was also started by a request to perform these operations and many others, no doubt, have had the same experience. We all have probably given the same answer, namely that we should be offered facilities to examine the candidates for such operations and discuss their indications, at the same time recording our observations on the condition of the ears, nose and throat.

I was well aware at the time that many operations were being done in this country upon the palatine and respiratory tonsils of school children for which the Ministry of Education had already granted certain facilities. Alison Glover (1938, *Proc. R. Soc. Med.*, xxxi, 1,219) reminds us that the number of tonsillectomies officially recorded in public elementary school children for the year 1919 were for London, 11,817 and for England and Wales, 42,004.

Has this development in the practice of otolaryngology in school children gone far enough? Has ear disease been satisfactorily treated in the young?

A world war has descended upon us again laying bare the defects in our armour. The medical boards of the Ministry of Labour and National Service have been and still are busy examining the youth of the country, and send to the otologist for his opinion the many cases of ear disease so often unconsciously tolerated and neglected by these young people no longer under the care of a school medical service.

Professor Canfield of Harvard (1945) showed an admirable colour film of the management of consultations in otolaryngology in a children's clinic in America. That, to me, was an example of how the work should be arranged. In my own, examinations are made in the presence of the parent or some responsible deputy who is questioned in simple language about the child's complaints. In one clinic the school medical officer is also present. The form originally designed by Kerr

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Love makes a useful case sheet and, when completed, a permanent record to be filed and consulted again

In their examination and treatment, the diseases of the outer ear do not call for special comment. But certain difficulties of management arise, as, for example, the case of keratosis obturans by no means uncommon in children. The study of the disturbances of the epithelial lining of the external auditory canal is our particular field of dermatology, but it is of importance also to us as surgeons for it leads to a better understanding of the behaviour of the epithelial covering which we hope will invade our operation cavities: those cavities of the hindmost end of the middle ear cleft laid open by radical or modified radical operations in the surgical treatment of chronic suppurative disease.

## THE PREVENTION OF DEAFNESS

In the prevention of deafness it is fortunate that syphilis in the future parent is better treated nowadays and we begin to understand how German measles infecting the pregnant mother may damage the auditory organ in the foetus, but until the problem of the early development of otosclerosis has been solved it is in the treatment of suppuration and the so called catarrhal conditions of the middle ear system where so much can be done for the young.

In case taking one finds many parents are deaf and in suppurative middle-ear disease I have seen repeatedly quite striking examples of a hereditary tendency.

There is some encouragement from the intermittent nature of childhood deafness, because we feel more hopeful of eventual recovery. Mother Nature, unaided, can do so much or we should find the hard of hearing more often in the adult population. Some years ago in Estonia E. Sarreste (1935) carried out researches in 1,366 pupils of schools in the city of Tartu. The ages varied from 7 to 20 years. He concluded that catarrhal otitis media diminishes with the age of the pupils and in the majority of children over 13 years of age there is less and less hope of improving the hearing, whereas below 13 years the greater number get well either spontaneously or as a result of rational treatment.

It is obvious that we must examine with specialist thoroughness the oropharynx, nose and post-nasal space and at once we are brought face to face with the tonsil problem.

Of the exact physiological significance of the palatine tonsils we remain uncertain. Schlemmer has insisted that they are an integral part of the pharyngeal lining and serve no separate functions. Glimstedt showed how the so called germ centres, absent at birth, develop thereafter as a reaction to invasion from the outside world, and to Grossmann and Waldapfel (1926) we owe an understanding of what goes on in these centres during acute tonsillitis. Policed as they are during health by mononuclear cells, they are entered in times of acute bacterial invasion by the polymorphonuclear leucocyte in the pursuit of organisms. To destroy these organisms or prevent their development we now have the assistance of the sulpha group of drugs but on the other hand we know that they may curtail the recruitment of the granular leucocyte.

Torsten Skoog (1936) provides an attractive answer suggesting the theory that the lymphadenoid tissue of the pharynx has a sensitizing effect on the reticulo endothelial system of the body.

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What I should like to know is to what extent the palatine tonsil influences the health of the middle-ear cleft. Considerable hypertrophy, presumably interferes with its proper ventilation though moderate enlargement may not. We know that acute tonsillitis as part of an acute inflammation of the pharyngeal lining is sometimes associated with acute otitis media. Perhaps I am concerned with the fear that indiscriminate removal will do harm.

I do not like the term chronic tonsillitis for it may be argued biologically that it is a normal process but there will be no disagreement that removal of the palatine tonsil regardless of its size cures that disease named most suitably by Continental writers—"tonsillitis with free intervals" and with brilliant results in the health of the child.

The examination of the nasopharynx in children is difficult but a trial with the post-nasal mirror in every case gives excellent practice and many successes and I have given up long ago the digital examination of the post-nasal space in children except under general anaesthesia.

It will be agreed that in infections of the middle ear and interference with its proper ventilation, the hypertrophied and diseased respiratory tonsil of Luschka should be removed surgically. There are, however, numerous conditions within the nasal passages of children which do not benefit materially from this operation and one of these is allergic or vasomotor rhinitis which is by no means uncommon. It is sometimes associated with secretory otitis.

Some years ago Proetz (1931) described acute allergic middle-ear attacks difficult to distinguish from the early stage of acute suppurative otitis media and Koch (1946) recently published a cytological study of middle-ear secretions in which he discusses the so-called eosinophil chronic otitis. There has been a call to our British Association of Oto-Laryngologists for closer co-operation between the paediatricians and ourselves. I should especially welcome their help in the solution of the problem of the so-called catarrhs including catarrhal middle-ear deafness which is not to be dismissed as one of essential eustachian obstruction.

Blegvad (1931) once asked the question: "Is it necessary to maintain as an independent malady the occlusion of the eustachian tube?" a question discussed later by Holmgren (1931) when describing his experimental research on its function. War has added interest to the problem because of aviation pressure deafness, a subject which has been introduced here by Simpson and discussed in detail by McGibbon (1942) and I understand that treatment by radiation has now been used to relieve it. I have no experience of radium or radon therapy as applied to the nasopharynx in the middle-ear deafness of children in the manner of Crowe and Guild (1938). The well-tried manoeuvre of inflation by Politzer's method gives brilliant if temporary relief in catarrhal otitis. Gone for a while is the depression of the drumhead and that strange grey translucent picture lightly coloured by a pink reflex from the tympanic wall. Some children are remarkably courageous to inflation but others are alarmed, perhaps there are members here to-day with memories of this experience in their own childhood and I have already remarked how fortunate we are that Nature alone does so much to relieve the growing child of his disability, but now and again we meet a striking case of the resistant eustachian tube. I have in mind a boy of 7 years, his right ear successfully ventilated by Politzer's method in November 1930, but later without success. In January, 1939, he retired at last from the

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unequal contest which had included several insertions of the Weber Leil intra tympanic tube and one temporarily successful paracentesis During those years reluctantly disturbing the peace of his school holidays I had repeatedly observed a collection of fluid in his middle ear Such difficulties recall to me a discussion opened here by Mollison (1934)

A depressing variety of middle ear deafness is one where in spite of rational medical surgical treatment to the nose and nasopharynx the child remains deaf The middle ear ventilates well and one cannot recognize through the drumhead any retained secretions or visible signs of adhesive processes I am reminded however that the late Sir William Milligan speaking some years ago in this room expressed the opinion that the round window placed as it is rather low in the tympanic wall is more readily exposed to pathological disturbances which eventually curtail its resilience

## SUPPURATIVE OTITIS MEDIA

In the treatment of acute suppurative otitis media we have had the opportunity at these meetings to discuss those newer aids the sulpha group of drugs and penicillin

If more children suffering from acute otitis were admitted to hospital and there had the assistance and proper control of the new therapeutics no doubt the incidence of chronic suppuration would fall

At the school clinic however it is most satisfactory to see so many discharging ears dry up and heal under simple conservative treatment by which I mean irrigation with a suitable mercurial lotion followed by the instillation of alcohol drops and the pursuit of granulations with the chromic acid bead

### *Lotion for Syringing*

R	Mercuric chloride	4 375 gr	(0 2838 g)
	Sodium chloride	4 375 gr	(0 2838 g)
	Methyl violet	0 01 gr	(0 00065 g)
	Aq ad	$\frac{3}{4}$ x	(300 0 c c)

Sig A tablespoonful to be mixed with three tablespoonfuls of warm water and used for syringing out the affected ear

See Sollvalla Hydrargyri Perchloridi in B P C 1923 p 1435 which gives methyl violet I prefer this to the methylene blue of the later edition The liquid is dispensed to the avoid danger of keeping mercurial tablets in the home

### *Spirit Drops*

R	Acid Boric	10 gr
	60% Alcohol	$\frac{3}{4}$ i

Sig Half a dozen drops to be run into the affected ear after washing out and drying with a cotton wool mop Repeat the drops later in the day after mopping out only

I do not wish to raise a controversy about the relative merits of the wet and the dry treatment I find syringing in the hands of the school and child welfare nurses eminently practical so long as they have the encouragement of parents and teachers in the regular attendance of the child

The aetiology of much chronic suppurative middle ear disease is rather mysterious We know how responsible are the acute infections and of the

exanthemata Kerr Love gave first place to measles but some cases develop in a strange manner especially in the attic region and we have the problem of cholesteatoma. Childhood naturally provides the most useful period in which to study them.

I should like to say a little about those cases selected for operation though not all of attic type. What I call the "black" mastoid is often seen. The cortex being carefully removed we notice at once a dark reflex which suggests the proximity of the lateral sinus, but proves to be the first of a widely disposed system of cells filled with a mucoid-like substance and lined by a darkly-stained membrane. I should like to know what happens to the mastoid system of such children who have avoided operation and perhaps disaster well into adult life. Might these cells be crowded out eventually by dense bone as far as the antrum?

In operations for attic disease we may find in children unsuspected cholesteatomatous deposits filling the cells right down to the tip of the mastoid process.

I should like to be better informed about the subject of cholesteatoma and the strange behaviour of the epithelium at the circumference of the tympanic ring. The child's ear provides special opportunity to observe the progress of moist defects of the membrana flaccida and the dry crusts which form in this area and to speculate, not without anxiety, what changes are taking place beneath them . . . I remember a publication by Marcus Diamant (1937). He believed that the otitic origin of cholesteatoma had not yet been proved and the title of his paper is in the form of a brief but significant question: Acute or Chronic Otitis? "

What kind of major operation should be done to drain the middle-ear system in children to treat disease inaccessible to conservative measures?

I prefer to be kind to the tympanic contents after laying wide open the attic, aditus, the mastoid antrum and the attendant cellular system. One hopes thereby to retain more of the hearing function, but the tympanic lining has considerable powers of recovery whereas the parts behind invaded in due time by a foreign covering of squamous epithelium are subject to changes of complexion. Might I be allowed to suggest that the younger otologist will be saved much wounding of his *amour-propre* by remembering that squamous epithelium lies uneasily upon bone.

Very occasionally I have performed completely radical mastoid operations on both ears in the child and I think of one, now grown up, who has given useful service to her country in the A.T.S., though how this enthusiastic volunteer managed to slip through the net of medical inspection nowadays I cannot say.

What of the after-treatment of the mastoid operation for chronic middle-ear disease in children? I prefer to cut a Ballance's flap of the soft meatal tube but would not cross swords with those of my colleagues who prefer to leave it uncut. A lightly filled rubber finger-stall is inserted and later removed with little pain to a child. The late Sir James Dundas-Grant thought well of this method.

When dressings have been removed the ear is washed out once or twice daily with weak eusol and later with the mercurial lotion which serves well after discharge from hospital. I am not depressed by some temporary filling of the cavity by nature in the healing process.

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Granulations of the meatus react well to the chromic acid bead and in time a layer of some depth recedes leaving epithelium on a hard seat. The child is now made safe, his general health improves remarkably and his morale has not been depressed by treatment of the ear with gauze packing.

In reading this Address I am aware that its teaching is elementary though supported inevitably by some experience provided by the passing of time, but we who practise medicine and surgery in this country are on the eve of great events. Our rulers are busy planning a comprehensive medical service for the nation and the problem of deafness has aroused fresh interest in high places. To help solve it we must begin with the child. I have no doubt that appeals by the otologist to develop his work for the children of the nation will be received with sympathy and that means will be provided to assure that it is well done.

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MR. FRANCIS MCGUCKIN said that they were all grateful for the President's provocative Address on a wide subject. There should be no such entity as tonsils and adenoids to be contracted out by local authorities. The otologist should have the review of the whole child, accompanied by a parent, preferably the mother. Too little note was taken of the historical contribution which could be made by the home doctor. It was time that the local authorities realized that the consultation and observation were just as important as—probably more important than—operative work. As far as was practicable, decisions should be taken by the surgeon who was to operate. His own preference would be that these services should form part of the hospital service rather than remain an isolated unit.

Some criticism of the term "catarrhal otitis" might be advantageous. There were several groups: (a) the accident of an acute otitis chiefly bacterial in type, (b) repeated acute otitis of varying severity, unilateral or bilateral, with satisfactory healing between attacks; (c) the otitic lesion which was chronic from the start; (d) recurrent negative pressure syndrome characterized by in-driven drum and a little retention fluid in the middle ear. In these cases the fluid was almost certainly not inflammatory and it was possible that it was no more than an accumulation of mucus not eliminated *via* the obstructed

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tube. A further group (*e*) was the permanent perforation syndrome with loss of protection from without and the failure of the air piston from within. In these cases the bigger the perforation the more frequent the otorrhœa, but the safer the nuisance.

In some of the aforesaid groups the mechanics and pathology were understood fairly well, but in others less well. Did the term "catarrhal otitis" really describe any definite group either in relation to pathology or simple mechanics? Did it cover a reasonable entity either in respect of the ear or the upper respiratory tract? Tonsils had little or no direct effect upon the ear, though acute diffuse infection involving the tonsils might spread to the ear, and anything producing great swelling of the palate might occlude the tube. The role of adenoids was fairly obvious.

He believed it was just as unscientific to hold the entity of eustachian obstruction as of bile-duct or urethral obstruction, without regard to the specific mechanical cause. In the past he had said that he knew of four definite causes, and he was still seeking for more. These causes were (1) trauma, which might arise from unskilled surgery with damage to the torus and possibly from a fracture involving the muscular relations of the eustachian tube (barotrauma with flutter valve obstruction might also be included); (2) neoplasms, simple or malignant; (3) œdema of the torus, secondary to inflamed lymphoid tissue attached perhaps to the posterior limb of the torus or secondary to a flow of pus over the cushion, e.g. antral suppuration with a deep uncinatè gutter or a sphenoidal suppuration (in these cases the rounded tubal entry could be seen to be reduced to a mere slit); (4) adenoids, in which case the usual obstruction arose from the mere covering of the tubal torus by the adenoid tissue, but he had already mentioned another possibility. The obstruction might be an uncomplicated mechanical thing or, if the cause be infective, then the aural result might be a mixture of inefficient in exchange plus bacterial complication.

There was no time to cover adequately the ætiology of chronic otitis, but he did hold the view that many cases—perhaps a considerable proportion—were chronic from the start, and he believed it was time the Section had a further full-scale discussion on cholesteatoma, which might include keratosis and aural dermoid. It had been his ambition, as yet unfulfilled, to have all the infantile ears in three hospitals in Newcastle observed and noted each day. He believed that in this way they might learn a great deal about the possibilities of congenital attic cholesteatoma and perhaps of primary pseudocholesteatoma. They had still to solve the problem of the acute ear which was smelly from the start and also of the extensive damage which might be quite unadvertised in the presence of a sterile cholesteatoma.

The President had coined the epigram "Squamous epithelium lies uneasily upon bone". That he fully agreed with, but it might also be added that keratinizing squamous epithelium might lie quite easily in the middle-ear cleft until such time as an accident occurred. Nothing more than moisture was required to turn this innocent condition into something threatening and destructive. The accident might be a common cold with a mild otitis, a visit to the swimming baths, or some other slight incident, but he thought they must admit that many of these cases were rendered active by the mere use of an ear syringe or the instillation of ear drops.

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The President had asked for information about radiotherapy in the post-nasal space. The speaker had tried this on a few occasions where other therapy seemed unsuitable. The numbers were insufficient to draw any conclusions, but he was prepared to be disappointed.

MR A S H WALFORD said that from experience around Cambridge he did not think there was any difference in the incidence of adenoids as between children from town or country. The condition had nothing to do with environment. The ordinary country population certainly had just as much adenoids as the town. There was also a considerable proportion of these children who were really suffering from antral infection rather than infected tonsils and adenoids.

MR J F SIMPSON exhibited some radon seed applicators which he had had made according to measurements provided by Major Fowler of the U.S. Air Force. These he had used in a very short series of cases. The small capsules which he exhibited, unscrewed and took a radon seed (75 millicuries). Both were put in the nose at the same time, after spraying with cocaine. They were rested against the orifice of the eustachian tube, the handles crossed at the anterior nares and tethered with a little piece of rubber band so as to bring them into contact with the eustachian orifice. It was calculated that at a depth of 0.5 cm from the wall of the capsule they would deliver a dose of the order of 750 r at each application. All these calculations had been made by the radio-physicist at St Mary's. It was very necessary in all this work to have the help of a radiotherapist. When using radon seeds allowance must be made in calculating the time of application for the gradual decline in activity of the radiation. The usual dosage, if the seed was fresh, was twenty-two minutes. The capsules were left *in situ* both together for this period and four such daily applications in succession constituted a course. More than one course was sometimes necessary and if the case required it one could wait two or three weeks, preferably three—before beginning another course.

Mr Simpson thought the treatment especially suitable for children in whom catarrhal deafness persists after removal of tonsils and adenoids and in whom politzerization gives only temporary improvement.

MR GAVIN YOUNG said that there were two main types of patients in this category. One consisted of the patients who suffered from nasal allergy, very often these were only children, and they did not appear to benefit at all, or benefited only very little from removal of tonsils and adenoids. The other consisted of patients with chronic antral disease. It might be that in the damp west of Scotland they met more of these cases than in the drier regions of the south, but certainly a considerable number of cases did not clear up because of chronic antral disease, and he felt that rhinology had failed so far to deal adequately with this subject by failing to elucidate the pathogenesis of the condition.

MISS WINIFRED HALL said that her interest in these cases had been rather from the sociological than the clinical side. She described the working of school children's clinics where the responsibility for treatment was divided among several people, and stressed the need for these children to be dealt with as hospital cases, where all ear, nose and throat conditions could be treated by the same surgeon, who would also have full use of the hospital's radiological and other facilities.



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MR. F. C. W. CAPPS said that otologists who were called on to advise upon the disposal of these children should also carry out the operative treatment, at any rate all major operations, and should have facilities to follow these children up afterwards. He was asked, about 1934, by the Chief Medical Officer of the L.C.C. to make a survey of the aural treatment of children in London. He found the aural clinics very scattered, quite isolated from hospitals and often in church halls and other unsuitable places. When operations were required they were sent away to a hospital outside London and operations were performed sometimes by men of very little experience in aural surgery. Some results were very bad. Much of this was in process of alteration when the war broke out, and the otologists running these clinics were being attached to a proper L.C.C. hospital with all facilities and ancillary services. Here they carried out the operations themselves, and all the necessary follow-up was done. This arrangement, which had given much improved results, broke down owing to the war, but he hoped that it would be revived.

As to chronic infection, or, perhaps not always "infection"—sometimes there was a chronic thickening of the lining of the mucosa of the antrum which led to improper ventilation or possibly improper insulation—he believed that in a large number of cases a routine X-ray picture of the sinuses was desirable. This need only be one view, to show the antra—the ethmoids were not so important as the antral cavity. He had found, too, that X-rays yielded valuable information upon nasal obstruction by adenoids. A true profile with soft tissue exposure was used.

He was prepared to confirm the President's impression that some of the cases of recurrent otitis media were hereditary.

MR. R. G. MACBETH suggested that although it was admirable in theory that an otologist should be in ultimate charge of the investigation of these children, it was perhaps impossible in practice for him to see all of them. He wondered whether there was not a place in the scheme for the school medical officer with special experience, possibly the D.L.O., to act as a filtration bed. Many routine cases could thus be dealt with, and those requiring the otologist selected. It would be a tragedy if otologists were able to do less than their duty to those children most needing help, because they were expected to see very large numbers.

MR. E. D. D. DAVIS said that he was in full agreement with the President, Mr. Capps and Miss Hall that all these cases should be examined thoroughly by an otologist in a properly equipped clinic. The patients should be examined again by the surgeon who undertakes any operation.

More could be done to prevent catarrhal infections in school children. The young child during his first term at school lost three-quarters of it through bad colds. Such a child is a carrier and should not go to school during a cold, but the mother complains that in that event the child lost his dinner and his free milk. He thought there should be some form of isolation. If a roll is called any child who showed signs of a cold should be inspected, and, if the temperature was above 99° he should be sent home or isolated with other similar children.

The ventilation was important. It is stated that the temperature of the

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schoolroom should not be above 65° A temperature above 65° meant that the ventilation was inadequate

He had seen cases treated by radium and deep X-ray therapy in which burns had occurred and the mucosa never recovered its normal condition. Serious damage had been done without any benefit to the patient. He advised every otologist to be guided by a skilled radiotherapist.

MR R SCOTT STEVENSON said that as we knew very little about the remote results of radium in the tissues of children it was to be hoped that it would not be used indiscriminately nor without careful supervision by an expert on radiotherapy.

MR W A MILL emphasized the dangers of unregulated radium treatment.

MR A M ROSS said that one point to which attention should be drawn was that general practitioners and the public were still not sufficiently alive to the dangers of ear trouble in children. The dangers tended now to be further masked by the tendency to give the sulphonamide drugs for earache without much discrimination.

DR J ALISON GLOVER said that the latest figures for public elementary school children in London for the incidence of running ears was 0.5 per cent, the figure was some nine times that when he first entered medicine, and all otologists were to be felicitated on so great a reduction. He was heartily in sympathy with those who had spoken about home conditions. These—and, of course, school conditions also—were most important factors in otitis. Perhaps school hygienic conditions were not quite so important as home conditions, but they were extremely important, and every improvement in school buildings and in the home was to be welcomed. Fortunately, the overcrowding necessitated by war conditions did not seem much to have affected the picture. For some reason or other the incidence of otitis, the mortality from rheumatic fever, and the incidence of the other streptococcal complications after measles and scarlet fever had all been going down recently.

Asked by a member whether it would help matters at all if otitis were to become a notifiable disease Dr Glover said that he would rather doubt whether formal compulsory notification would be helpful.

THE PRESIDENT, in replying said that the question of "acute or chronic otitis" in relation to the origin of chronic middle ear suppuration led one to inquire into the difficult problem of how cholesteatoma originated.

Mr Simpson had shown how the "cross-legged" method recommended by Fowler was used for his radon applicators so that the applicators would remain closely applied to the region of the eustachian orifices. He himself feared to use radiation in any form. After all, the pituitary was not very far away and though it was true it was shielded by bone, it was the key gland of the endocrine system and serious consequences might follow if it were disturbed.

Mr Davis had suggested that the otologist was worthy of his hire. Those in authority could not neglect the problem of the prevention of deafness and that of the complications attendant on middle ear suppuration. The otologist must also perform a certain number of operations on the lymphadenoid tissue of the throat.

Mr Scott Stevenson also had uttered a warning about the use of radiation. Among other points raised was the general practitioner's over-use of the

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sulpha drugs, but nevertheless he would rely on the judgment and wide experience of the general practitioner in their administration, though warn him of cases of persistent deafness and latent mastoiditis which sometimes followed the abatement of acute symptoms.

## ABSTRACTS

### EAR

*The Two-place Theory of Hearing* GORAN DE MARE *Acta Otolaryngologica*, 5, LXXIV, 1/9 October 31st 1946

The author is discussing a paper of Ruedi and Furrer *Acta Otolaryng*, LXXIII, 460. He considers that the two place theory of hearing supersedes the resonance theory of Helmholtz as a working hypothesis and gives reasons for this. A considerable amount of experimental work done by the author is mentioned to support this contention. This paper is of considerable help for those attempting to understand the physiology of hearing.

G. H. BATEMAN

*Studies on the effect upon the hearing through Air Conduction brought about by Variations of the Pressure in the Auditory Meatus* HELMER RASMUSSEN *Acta Otolaryngologica* 5 LXXIV 1/9 October 31st 1946

Using a modification of the pneumophone of Dishoeck the author has examined the variation in hearing caused by raising and lowering the pressure in the external auditory meatus. As was expected the hearing for most frequencies was reduced by both increase and decrease of the pressure. However with certain frequencies around 8,000 cycles the loudness of the tone was increased by a high over pressure about 30 to 50 centimetres of water. He discusses the possible explanations of this unexpected phenomenon.

G. H. BATEMAN

*The Inter Attico-Tympanic diaphragm in the newly born* CHATELLIER, H. P. and LEMOINE J. *Les Annales D Oto Laryngologie* 1946 XIII, 11 12, 434-466

A detailed account of the anatomy of the middle ear of the infant is given. This description is based on the study of three dimensional models of the middle ear, built from superimposed photomicrographs on glass plates produced from a series of tissue sections.

The authors conclude that the infantile tympanic cavity is incompletely subdivided into an upper and a lower cavity by a transverse horizontal septum, which they call the inter attico tympanic diaphragm.

The upper cavity which consists of the attic and aditus communicates with the lower cavity—the tympanic cavity proper—by means of a small aperture in the transverse horizontal diaphragm. This aperture measures 2 mm in diameter and is situated between the stapes and processus cochleariformis.

In otitis media the upper cavity may be cut off by oedematous occlusion of this aperture, and although the lower cavity may drain and clinical resolution

may appear complete, yet after an interval mastoiditis may develop due to backward extension from the undrained upper cavity.

The article is well illustrated by photomicrographs and diagrams, and clinical cases are quoted in support of the applied anatomy.

I. A. M. MACLEOD.

*A better surgical approach for Neoplasms of the Eustachian Tube.* JACOB MAURICE. *Les Annales D'Oto-Laryngologie*, 1946, xiii, 7-8, 322-332.

A detailed description of an oblique approach for tumours of the eustachian tube and lateral nasopharyngeal wall is given. Briefly the method is as follows :

Using an external paranasal incision on the side opposite to the lesion, the maxillary antrum is freely opened. The medial wall of the antrum is removed, exposing the nasal cavity and the septum. By resecting the posterior portion of the septum a good exposure of the lateral naso-pharyngeal wall is obtained. The advantages claimed for this approach are :—

1. Ease of access,
2. Clear field of vision,
3. Avoidance of mutilation.

The importance of combining radiotherapy with surgery in such cases is stressed. The author is in the habit of operating 4-5 weeks after the cessation of a course of radiation by lateral fields.

I. A. M. MACLEOD.

## LARYNX

*Surgical Treatment of Intractable Laryngeal Stenosis.* AUBRY, M. *Les Annales D'Oto-Laryngologie*, 1946, xiii, 11-12, 567-572.

The author describes his operative technique for the relief of old standing laryngeal stenosis due to partial loss of the cartilaginous framework, where other methods have failed and a tracheotomy tube is worn.

The operation is conducted in two stages. The first aims at establishing the lumen of the glottic and subglottic areas. The second is designed to increase the lateral and antero-posterior diameters of the supra-glottic region.

Stage 1.—The larynx is opened through a vertical mid-line incision and the lumen in the glottic and subglottic regions is re-established by excising any scar tissue, at the same time conserving healthy mucous membrane. The raw surface is then covered by a skin graft obtained from the neck. The lumen of the cavity is maintained by a stent mould and the larynx is closed.

Stage 2.—Three weeks after completion of Stage 1 the larynx is again opened by a fresh vertical incision. Scar tissue obstructing the lumen in the supra-glottic region is excised. A transverse incision is then made at the level of the hyoid. Dissection frees the body and one greater cornu of the hyoid bone, leaving the other cornu undisturbed. The mobilized hyoid is then swung obliquely downwards and the free greater cornu is sutured to the inner surface of the corresponding ala of the thyroid cartilage.

The epiglottis is drawn forwards and anchored to the pre-hyoid tissues by two deep chromic catgut sutures passed round its base. A stent mould is placed in the cavity and the transverse and vertical incisions closed.

# Œsophagus

The mould is removed at the end of six weeks and the tracheotomy opening is closed

By tending to return to its original horizontal position, the hyoid keeps the ala of the thyroid prised laterally, and thus maintains the lateral diameter of the laryngeal lumen

For details of technique the reader is advised to consult the author's original article

I A M MACLEOD

## ŒSOPHAGUS

*Two Cases of Œsophageal Paralysis* ESCHBACH H and BONHOMME L *Les Annales D Oto Laryngologie*, 1946, xiii, 9 and 10, 458-461

Two interesting cases of œsophageal paralysis are noted

I Œsophageal paralysis was the first manifestation of post diphtheritic paralysis, drop foot subsequently developing There was no palatal paralysis

II The œsophageal paralysis was due to botulism and was associated with paralysis of the soft palate and the ocular muscles of accommodation

In both cases dysphagia was complained of Barium swallow showed a very rapid descent of the barium and œsophagoscopy was remarkably easily performed due to the gaping patulous œsophagus

I A M MACLEOD

## MISCELLANEOUS

*Bullous Eruptions of the Upper Respiratory Tract* BOUELET and LABAYLE *Les Annales D Oto Laryngologie*, 1946, xiii 7-8 289-302

A discussion is given on the classification and differential diagnosis of bullous eruptions occurring in the upper respiratory tract Particular reference is made to a type of lesion seen during the German occupation This consisted of a painless bulla or group of 3-4 discrete bullae situated on the base of the uvula the pillars of the fauces or the posterior pharyngeal wall Those bullae were often hæmorrhagic but there was no inflammatory change in the surrounding mucosa

No systemic upset accompanied the lesions which persisted for 2-3 weeks and healed without scarring

Vitamin deficiency was thought to be a causal factor

I A M MACLEOD

## LETTER TO THE EDITOR

TO THE EDITOR, *The Journal of Laryngology and Otology*.

DEAR SIR,

In response to the inquiry made by Dr. Tumarkin in your *Journal* of October, 1946, I wish to state that my view concerning the relatively shortened bone conduction may hardly be tenable.

The studies on which this view was based were carried out some 20 odd years ago, when the loss of hearing for air and bone conduction was not calculated in decibels, and thus I happened erroneously to reckon with too great a loss for the bone conduction.

This apparent discrepancy between air and bone conduction became the more striking as the examinations were not carried out in a sound-proof room.

*Commune Hospital,  
Copenhagen.*—May 12th, 1947.

DIDA DEDERDING.

### IMPORTANT NOTICE

This issue completes the *Journal* for 1946. Owing to paper and other shortages it has been found to be impossible to catch up with the year 1947 and so bring the issues up to the current month. As it is most unsatisfactory and confusing, both from authors' and readers' points of view, to publish articles a year after they have been written, it has been decided to eliminate entirely the year 1947, so that the next issue will be dated January, 1948.

WALTER HOWARTH.

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